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AUTOMATIC SOLUTION OF PUCHER'S EQUATION

by

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ABSTRACT

The system of shell membrane force-equilibrium equations expressed in terms of cartesian coordinates can be reduced to a single differential equation, called Pucher's equation, involving a stress function and the coordinate defining the elevation of the shell surface. A computer program which completely automates the solution of Pucher's equation is described. This program is restricted to the case where the loading is vertical and the projected shell boundary consists of straight line segments. Collatz's method is used to establish a system of difference equations. Results for an elliptic paraboloid of rectangular plan and a paraboloid of revolution having a triangular boundary are compared with the exact solutions. Listings, flow charts, and a description of the program are given.

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1. INTRODUCTION

In most problems of analysis and design of shell structures, the membrane theory plays an important role. It usually yields the contribution of the surface loading to the state of stress and in many cases a design based on the results of the membrane theory has to be corrected only in regions near the boundary of the shell. In such problems the geometry of the shell is specified and the equilibrium equations of the membrane theory are solved for the stress resultants.

Alternatively, the stress resultants may, with some restrictions, be specified throughout the shell and the membrane equilibrium equations solved for the parameters defining the shape of the shell. This could be considered as a first step toward a direct design of the shell, i.e. a design in which the shape of the middle surface and the thickness of the shell are determined such that under a given surface loading the shell behaves according to prescribed conditions. A desirable behavior is that of essentially uniform direct stress throughout the shell under the sustained loading. The advantages of such a design method would be many. From a structural point of view the behavior of the shell would be as efficient as possible. The design process could be greatly simplified if complicated analysis could be avoided. Functional shapes may have significant esthetic value or may at least be a source of valid inspiration for the architect.

The specified membrane behavior cannot be completely arbitrary but is subject to the same restrictions as implied in conventional membrane analysis. The limitations of the membrane theory are generally related to the type of surface loading, the surface geometry and the boundary conditions of the shell. A more detailed discussion of these points can be found in [1].* However, the membrane theory is sufficiently important for the analysis and design of shell structures to warrant automating the calculations for conventional membrane stress analysis and for membrane shape determination. These two aspects of the membrane theory are considered in this report.

---

* Numbers in brackets refer to references listed at the end of this paper.

2. THEORETICAL CONSIDERATIONS

2.1 Special form of Pucher's equation

The membrane force-equilibrium equations expressed in terms of cartesian coordinates (x, y, z) can be reduced to a single differential equation involving a membrane stress function, F(x, y), and z(x, y), the coordinate defining the middle surface. This equation was originally developed by Pucher [2]. A detailed derivation of Pucher's equation is contained in [1]. The results for the case of a vertical surface loading (z direction) are summarized below.

Figure 1 shows the actual and projected stress resultants. They are related by

$$N_{xx} = \left[\frac{1 + z_{,x}^2}{1 + z_{,y}^2}\right]^{1/2} \overline{N}_{xx} \qquad N_{yy} = \left[\frac{1 + z_{,y}^2}{1 + z_{,x}^2}\right]^{1/2} \overline{N}_{yy}$$

$$N_{xy} = N_{yx} = \overline{N}_{xy} = \overline{N}_{yx} \tag{1}$$

where

$$z_{,x} = \frac{\partial z}{\partial x} \qquad z_{,y} = \frac{\partial z}{\partial y} \tag{2}$$

We will generally use subscript notation to denote partial differentiation. The definition equations for the membrane stress function are:

$$\begin{aligned} \overline{N}_{xx} &= F_{,yy} \\ \overline{N}_{yy} &= F_{,xx} \\ \overline{N}_{xy} &= -F_{,xy} \end{aligned} \tag{3}$$

Equation (3) applies only for the case where the surface loading acts in the z direction. If the surface loading has components in either the x or y directions, particular integrals involving these components must be added to the expressions for N_{xx} and N_{yy}. Using (3) the membrane force equilibrium equations reduce to the following single equation called Pucher's equation,

$$z,_{yy} F,_{xx} - 2z,_{xy} F,_{xy} + z,_{xx} F,_{yy} = - \overline{P}_z \tag{4}$$

where $\overline{P}_z$ is the surface loading per unit <u>projected</u> area acting in the + z direction. The expressions for the projected boundary forces (see Figure 1) in terms of F and z are

$$\begin{aligned}
\overline{N}_{nn} &= F,_{yy} \sin^2\alpha + 2F,_{xy} \sin\alpha\cos\alpha + F,_{xx} \cos^2\alpha \\
\overline{N}_{ns} &= \sin\alpha\cos\alpha(F,_{yy} - F,_{xx}) + (\cos^2\alpha - \sin^2\alpha) F,_{xy} \\
\overline{N}_{nz} &= - z,_y F,_{xx} \cos\alpha + z,_x F,_{yy} \sin\alpha + (z,_x \cos\alpha \\
&\quad - z,_y \sin\alpha) F,_{xy}
\end{aligned} \tag{5}$$

2.2 Analysis and design phases

In conventional membrane stress analysis, z(x, y) is prescribed. We solve Pucher's equation for F(x, y), subject to appropriate boundary conditions on F, and then determine the projected stress resultants using the definition equations for F. In membrane shape determination, we specify F(x, y) and solve Pucher's equation for z subject to appropriate boundary conditions on z. We refer to these two computations as the "analysis phase" and the "design phase."

This study is restricted to the case where the surface loading is vertical and the boundary is defined by a set of vertical plane curves. Since the plane of each curve is perpendicular to the x - y plane, the projection of the boundary on the x - y plane consists of a set of straight line segments. These restrictions simplify the govern-

ing equations. They are also quite reasonable, from a practical point of view.

In the analysis phase, we take the boundary condition for F as $F = 0$. This boundary condition corresponds to the case where there is negligible restraint against horizontal (x - y plane) displacement normal to the boundary (see [1]). The problem of analysis involves solving (4) subject to the condition, $F = 0$, on the boundary.

In the design phase, we take the specified behavior of $F(x, y)$ as

$$
\begin{aligned}
F,_{yy} &= \overline{N}_{xx} = \overline{N} = \text{const.} \\
F,_{xx} &= \overline{N}_{yy} = \overline{N} \\
F,_{xy} &= 0
\end{aligned}
\tag{6}
$$

The actual stress resultants corresponding to (6) are

$$
\begin{aligned}
N_{xx} &= \left(\frac{1 + z,_x^2}{1 + z,_y^2}\right)^{1/2} \overline{N} \\
N_{yy} &= \left(\frac{1 + z,_y^2}{1 + z,_x^2}\right)^{1/2} \overline{N} \\
N_{xy} &= N_{yx} = 0
\end{aligned}
\tag{7}
$$

and the design problem reduces to solving

$$
z,_{xx} + z,_{yy} = -\frac{\overline{P}_z}{\overline{N}} \tag{8}
$$

subject to the condition that z is prescribed in the boundary. The projected normal boundary force does not vanish for this specified behavior of F. Actually,

$$
\overline{N}_{nn} = \overline{N} \tag{9}
$$

from (5). If this boundary force is not applied, the actual behavior may be quite different from the desired behavior.

2.3 General computational procedure

In both analysis and design, the problem reduces to solving a second order partial differential equation ((4) for analysis and (8) for design). The computational procedure employed to solve these equations is outlined below.

1. A square grid is constructed over the projection of the shell on the x - y plane.
2. Using the Taylor series expansion approach developed by Collatz [3] and later applied by Engeli [4] to elliptic differential equations, the differential equation is replaced by a difference equation at each interior point. Since (8) is a special case of (4), we develop the procedure for (4) and then specialize it for the design phase.
3. The resulting system of linear algebraic equations is solved by Gauss elimination. We work with the partitioned system and take advantage of the tri-diagonal character of the partitioned coefficient matrix.

A digital computer program which completely automates the above computations has been developed and coded for the IBM 7094. This program is divided into four basic parts. The operations performed in the various parts are:

1. Input, sorting, preliminary calculations.
2. Automatic assemblage of difference equations for the interior grid points.
3. Automatic assemblage of difference equations for points on the boundary.
4. Solution of the final system of equations, back substitution and output.

The program allows for two forms of geometrical input in the analysis phase. One can express z as a third degree polynomial. The various derivatives of z are calculated using the corresponding continuous expressions for the derivatives. Alternately, one can specify z

at the interior grid points and at points along the boundary. In this case, the derivatives are determined using Collatz's approach. For both cases, $\bar{p}_z$ has to be specified at all the grid points. The output for the analysis phase consists of the actual stress resultants (N_{xx}, N_{xy}, N_{yy}) at the interior points and the projected boundary forces ($\bar{N}_{ns}$, $\bar{N}_{nz}$) at various points on the boundary.

In the design phase, $\bar{p}_z$ has to be specified at all the grid points and z must be specified at points along the boundary. The output consists of the actual stress resultants and elevation at the grid points and reactions at various points on the boundary.

In what follows, we first describe the procedure used to establish the difference equation for a point adjacent to a boundary. Next, we briefly describe how the system of difference equations is assembled and solved utilizing the quasi-tridiagonal property of the partitioned coefficient matrix. Finally, we compare the calculated (this program) and exact results for an elliptic paraboloid of rectangular plan and a paraboloid of revolution having a triangular projected boundary.

2.4 Automatic procedure for establishing difference equations

In the finite difference approach, the function is determined only at discrete points. At each discrete point, the differential equation is replaced by an algebraic equation, generally called a difference equation, which relates the function at the particular point and certain neighboring points. The essential difficulty of the finite difference method involves determining what neighboring points should be used to approximate a particular differential operator to a certain degree of accuracy.

Collatz [3] has developed an easily automated procedure for establishing the difference equation in a consistent manner. His method utilizes the Taylor series expansion for a function in the neighborhood of a point, say $x = x_i$.

$$f\ (x_i + \Delta x) = f_i + f_i' \Delta x + \frac{1}{2} f_i'' (\Delta x)^2$$

$$+ \ . \ . \ . + \frac{1}{n!} f_i^n (\Delta x)^n + \ . \ . \ . \qquad (10)$$

where

$$f_i = f(x_i)$$

$$f_i^n = \left.\frac{d^n f}{dx^n}\right|_{x = x_i}$$

Consider the differential equation,

$$L(f) = q(x) \tag{11}$$

where L represents a linear differential operator. We use (10) to determine the molecule for $L(f_i)$ corresponding to a specified degree of accuracy. The molecule indicates which neighboring points are used, and also specifies the coefficients of the (unknown) values at these points as they appear in the difference equation. In general, we express $L(f_i)$ as a linear combination of adjacent values of f. The number of points that must be considered depends on the desired accuracy, that is, on the order of the highest nonvanishing derivative contained in the expansion.

We illustrate the procedure for

$$L(f) = f'' \tag{a}$$

To simplify the algebra, we consider the points to be equally spaced. The procedure can be readily extended to handle non-uniform spacing. Suppose we want an approximation for f" at point 1 which involves the values of f at points 1, 2, and 3 (see Figure 2). First, we express f_1'' as

$$f_1'' = c_1 f_1 + c_2 f_2 + c_3 f_3 + E \tag{b}$$

where c_1, c_2, c_3 are unknown constants. Next, we determine the Taylor series expansions for f_1, f_2 and f_3 with respect to point 1.

$$f_1 = f_1$$

$$f_2 = f_1 + h\, f_1' + \frac{h^2}{2} f_1'' + \frac{h^3}{6} f_1''' + \frac{h^4}{24} f_1^{iv} + \ldots \qquad \text{(c)}$$

$$f_3 = f_1 - h\, f_1' + \frac{h^2}{2} f_1'' - \frac{h^3}{6} f_1''' + \frac{h^4}{24} f_1^{iv} + \ldots$$

We list (c) in transposed form.

row factors	f_1	f_2	f_3	f_1''
f_1	1	1	1	0
f_1'	0	h	$-h$	0
f_1''	0	$h^2/2$	$h^2/2$	1
f_1'''	0	$h^3/6$	$-h^3/6$	0
f_1^{iv}	0	$h^4/24$	$+h^4/24$	0
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

(d)

We have also added the Taylor series expansion for f_1'' at point 1, which consists of

$$f_1'' = f_1''$$

The common factors f_1, f_1', f_1', f_1'', etc. appearing in the rows have been moved to the extreme left.

Now we see from (b) that a linear combination of the first three columns of (d) should be equal the fourth column. The unknowns are the column factors (c_1, c_2, c_3). Considering only the first three rows of (d), i.e. satisfying the equations up to the second derivative, we have

$$c_1 + c_2 + c_3 = 0$$

$$h\,(c_2 - c_3) = 0 \qquad \text{(e)}$$

$$\frac{h^2}{2}\,(c_2 + c_3) = 1$$

The solution of (e) is

$$c_2 = c_3 = \frac{1}{h^2}$$

$$c_1 = -\frac{2}{h^2} \qquad \text{(f)}$$

Substituting into the remaining equations, we see that equation 4 is identically satisfied. Actually, row 4 is a multiple of row 2. The fifth equation leads to a contradiction and thus determines the order of the approximation.

$$\frac{h^4}{24}\,(c_2 + c_3) = \frac{h^2}{12} \neq 0$$

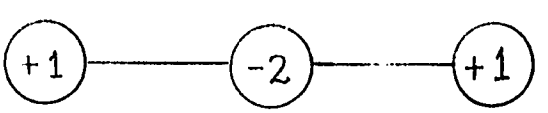
Then,

$$f_1'' = \frac{f_2 - 2\,f_1 + f_3}{h^2} + E \qquad \text{(g)}$$

where

$$E = -\frac{h^2}{12}\,f_1^{iv} + \ldots$$

The molecule for f" (for an error of the order of h^2) is



If point 1 lies near the boundary, the boundary conditions have to be taken into consideration. Let us assume that point 3 lies on the

boundary and f_3' is prescribed. Equation (g) is not applicable for this case and we must determine a new molecule which incorporates the boundary condition at x_3.

We develop the Taylor-series expansion for $h\ f_3'$ with respect to point 1. The Taylor series expansion for a derivative is determined by replacing the function f in equation (10) by the derivative.

$$h\ f_3' = h\ (f_1' - h\ f_1'' + \frac{h^2}{2} f_1'' - \frac{h^3}{6} f_1^{iv} + \ldots) \qquad \text{(h)}$$

Adding the expansions for the function at 1, 2 and 4 leads to the following set of columns:

row factors	(1) $h\ f_3'$	(2) f_1	(3) f_2	(4) f_4	(5) f_1''
f_1	0	1	1	1	0
f_1'	h	0	h	$2h$	0
f_1''	$-h^2$	0	$h^2/2$	$2h^2$	1
f_1'''	$+h^3/2$	0	$h^3/6$	$(4/3)h^3$	0
f_1^{iv}	$-h^4/6$	0	$h^4/24$	$(2/3)h^4$	0
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.

(i)

If we want the same order approximation as before (contradiction in the equation with the fourth derivative, i.e., the fifth row) we must satisfy

$$c_1\ (\text{col. } 1) + c_2(\text{col. } 2) + c_3(\text{col. } 3) + c_4(\text{col. } 4) = \text{col.}5 \qquad \text{(j)}$$

identically up to the fourth row. The equations follow from (i).

$$c_2 + c_3 + c_4 = 0$$

$$c_1 + c_3 + 2\,c_4 = 0$$

$$-\,c_1 + \frac{1}{2}\,c_3 + 2\,c_4 = \frac{1}{h^2} \tag{k}$$

$$\frac{1}{2}\,c_1 + \frac{1}{6}\,c_3 + \frac{4}{3}\,c_4 = 0$$

$$c_1 = -\frac{6}{11\,h^2} \qquad c_2 = -\frac{4}{11\,h^2} \qquad c_3 = c_4 = \frac{2}{11\,h^2}$$

The fifth row is not identically satisfied and determines the order of the approximation. The resulting expression for f_1'' is

$$f_1'' = \frac{-\,6(hf_3') - 4f_1 + 2f_2 + 2f_4}{11\,h^2} - \frac{29}{132}\,h^2\,f_1^{iv} \tag{ℓ}$$

If we consider only points 1 and 2 along with the boundary condition, we obtain a valid expression for f_1'' but the error involves f_1''' instead of f_1^{iv}. The result for this case is

$$f_1'' = \frac{-\,2(hf_3') - 2\,f_1 + 2\,f_2}{3\,h^2} - \frac{2}{9}\,h\,f_1''' \tag{m}$$

The linear dependency (row 2 = row 4) that leads to the higher order of approximation in (g) is due to symmetry. Even without formulating boundary conditions, the symmetry would be destroyed by choosing points 3 and 2 at different distances from point 1.

Suppose we want to determine difference equations for other differential operators, e.g. f', using the same points. The left-hand side of the system of equations is the same; we only have to add an additional right hand side for every differential operator, consisting of the Taylor-series-expansion. Basically the same approach can be used to assemble many-point difference equations (see [3], [4]).

Comparing this procedure to conventional methods (difference operators), we see that boundary conditions can be incorporated in a consistent way. The order of approximation can be specified and applies to points in the interior and near the boundary. No points on or outside the boundary are used. It is also possible to get difference equations for derivatives of the unknowns (e.g. f_1') by processing more than one right hand side. Here again, the order of approximation is consistent, and accuracy is not lost by differentiation.

The two-dimensional Taylor series expansion for f(x, y) in the neighborhood of (x_A, y_A) has the form:

$$
\begin{aligned}
f(x_A + \Delta x, y_A + \Delta y) = {} & f_A + f_{A,x} \Delta x + f_{A,y} \Delta y \\
& + 1/2\ (f_{A,xx} \Delta x^2 + 2f_{A,xy} \Delta x \Delta y + f_{A,yy} \Delta y^2) \\
& + 1/6\ (f_{A,xxx} \Delta x^3 + 3f_{A,xxy} \Delta x^2 \Delta y \\
& + 3f_{A,xyy} \Delta x \Delta y^2 + f_{A,yyy} \Delta y^3) \qquad (12) \\
& + 1/24\ (f_{A,xxxx} \Delta x^4 + 4f_{A,xxxy} \Delta x^3 \Delta y \\
& + 6f_{A,xxyy} \Delta x^2 \Delta y^2 + 4f_{A,xyyy} \Delta x \Delta y^3 \\
& + f_{A,yyyy} \Delta y^4) \\
& + \ldots
\end{aligned}
$$

We obtain the expansion for a partial derivative by replacing f by the derivative. For example, the expansion for $f,_{xx}$ has the form

$$
\begin{aligned}
f,_{xx}(x_A + \Delta x, y_A + \Delta y) = {} & f_{A,xx} + f_{A,xxx} \Delta x + f_{A,xxy} \Delta y \\
& + 1/2\ (f_{A,xxxx} \Delta x^2 + 2f_{A,xxxy} \Delta x \Delta y \qquad (13) \\
& + f_{A,xxyy} \Delta y^2) \\
& + \ldots
\end{aligned}
$$

The procedure for the two-dimensional case is the same as for the one-dimensional case. First, we expand the function at certain neighboring points in terms of the function and its derivatives at the central point. We generally refer to the central point as point 1 and the neighboring points as points 2, 3, ..., n. Next we expand the differential operator $L(f_1)$ at the central point. The problem consists of determining a set of constants, $c_1, c_2, \ldots, c_n$, such that

$$\sum_{j=1}^{n} c_j f_j = L(f_1) + E \tag{14}$$

where E is the prescribed error. One can visualize (14) as a system of algebraic equations. We list the expansions for $f_1, f_2, \ldots, f_n$ and $L(f_1)$ vertically and require that

$$\sum_{j=1}^{n} c_j f_j = L(f_1)$$

be satisfied up to a certain row, say row k. The first nonvanishing term in the remaining rows (k+1, k+2, . . .) of $\sum_{j=1}^{n} c_j f_j$ determines the order of the error, E. The number of points required depends on k; we need, at most, k points for the general case.

We illustrate the procedure for the following operator:

$$L(f) = a_1 f,_{xx} + a_2 f,_{xy} + a_3 f,_{yy} \tag{a}$$

where a_1, a_2, a_3 are functions of x and y. The locations of various neighboring points are shown in Figure 3. We have taken a constant spacing, h, to simplify the analysis. The factored expansions for $f_1, f_2, \ldots, f_9$ and $L(f_1)$ up to the fifth derivative are listed below. The "row factor" column contains the factor for each row. For example, we multiply row 6 by $(h^2/2)\, f_{1,yy}$ to obtain the actual row.

		1	2	3	4	5	6	7	8	9	10
	row factor	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	$L(f_1)$
1	f_1	1	1	1	1	1	1	1	1	1	0
2	$hf_{1,x}$	0	1	-1	0	0	1	-1	-1	1	0
3	$hf_{1,y}$	0	0	0	1	-1	1	-1	1	-1	0
4	$(h^2/2)f_{1,xx}$	0	1	1	0	0	1	1	1	1	$2a_1/h^2$
5	$h^2 f_{1,xy}$	0	0	0	0	0	1	1	-1	-1	a_2/h^2 (b)
6	$(h^2/2)f_{1,yy}$	0	0	0	1	1	1	1	1	1	$2a_3/h^2$
7	$(h^3/6)f_{1,xxx}$	0	1	-1	0	0	1	-1	-1	1	0
8	$(h^3/2)f_{1,xxy}$	0	0	0	0	0	1	-1	1	-1	0
9	$(h^3/2)f_{1,xyy}$	0	0	0	0	0	1	-1	-1	1	0
10	$(h^3/6)f_{1,yyy}$	0	0	0	1	-1	1	-1	1	-1	0
11	$(h^4/24)f_{1,xxxx}$	0	1	1	0	0	1	1	1	1	0
12	$(h^4/6)f_{1,xxxy}$	0	0	0	0	0	1	1	-1	-1	0
13	$(h^4/4)f_{1,xxyy}$	0	0	0	0	0	1	1	1	1	0
14	$(h^4/6)f_{1,xyyy}$	0	0	0	0	0	1	1	-1	-1	0
15	$(h^4/24)f_{1,yyyy}$	0	0	0	1	1	1	1	1	1	0

Suppose we want the error to involve fourth (and higher) derivatives. The, we must satisfy

$$\sum_{j=1}^{n} c_j f_j = L(f_1)$$

identically up to row 10 in (b). In the general case, we would need 10 points. However, only 8 points are required for this case since there are only 8 linearly independent rows in (b). The rows are related by

$$\begin{aligned} \text{row } 2 &= \text{row } 7 \\ \text{row } 3 &= \text{row } 10 \end{aligned} \tag{c}$$

It should be noted that the linear dependency of the rows is due to the symmetrical location of the points and the form of the operator.

Rather than work with only 8 points, it is more convenient to work with all nine points since the resulting molecule is symmetrical. The solution for points 1, 2, . . . , 9 is

$$\begin{aligned} c_1 &= (-2/h^2)\ (a_1 + a_3) \\ c_2 &= c_3 = a_1/h^2 \\ c_4 &= c_5 = a_3/h^2 \\ c_6 &= c_7 = a_2/h^2 \\ c_8 &= c_9 = -a_2/h^2 \end{aligned} \tag{d}$$

Using (d), the difference equation for (a) is

$$\begin{aligned} a_1 f_{1,xx} + a_2 f_{1,xy} + a_3 f_{1,yy} &= (-2/h^2)\ (a_1 + a_3) f_1 \\ &+ (a_1/h^2)\ (f_2 + f_3) + (a_3/h^2)\ (f_4 + f_5) \\ &+ (a_2/h^2)\ (f_6 + f_7 - f_8 - f_9) \end{aligned} \tag{e}$$

The error associated with (e) is of the order of h^2 times various fourth order derivatives.

$$E = (h^2/12)(a_1 f_{1,xxxx} + a_3 f_{1,yyyy}) + (2a_2/3)\, h^2\, (f_{1,xxxy} + f_{1,xyyy}) + \text{higher order derivatives} \qquad (f)$$

One can obtain the difference equations for $f_{,xx}$, $f_{,xy}$, $f_{,yy}$ by specializing (e).

Equation (e) applies when all the points (i.e., 2 through 9) are inside the domain. If one point is missing, we can still work with the remaining 8 points. Additional points are needed only when two or more points of the molecule are missing. In this case, we first formulate the boundary conditions and then take as many additional points as are requried to satisfy the first 10 equations. It should be noted that the linear dependency of the rows depends on the operator. If L(f) involves either first or third derivatives, say $f_{,x}$ or $f_{,xxx}$, the equations defined by the first ten rows will <u>not</u> be consistent. One of the first 9 points must be disregarded and two additional points from the set (10, 11, . . ., 25) must be used to obtain the desired accuracy.

The decision as to whether one should include boundary conditions and which additional gridpoints should be chosen is somewhat arbitrary. In this study, we take the distance from the central gridpoint to the boundary as the criteria for deciding whether the boundary condition should be enforced. The inclusion of boundary conditions will in general destroy the linear dependency of the rows (e.g., see the one-dimensional example). To guarantee the same order of approximation as at an interior point, we need ten columns which are linearly independent up to the tenth row. This may neccsitate using gridpoints with relative numbers 10 and up.

We let d be the distance from the central point to a side and let h be the grid spacing. If

1. $d > h\sqrt{2}$, no boundary condition is formulated.
2. $(h\sqrt{2}/2) < d < h$, the boundary condition at the closest point on the side is included.
3. $d \leq h$, the boundary conditions at the closest point and at points a distance h from this point in both directions are included.

Additional gridpoints, starting with the lowest relative number (see Figure 3), are selected after the boundary conditions have been formulated. In general, up to 6 boundary conditions may be included. Various cases are shown in Figure 4.

This procedure can lead to identical columns (if two sides include the same cornerpoint as one of the boundary points.) From a computational point of view, a linear dependency may also arise if two boundary points are quite close. Let NBC denote the number of boundary conditions included. To obtain 10 linearly independent columns (up to the tenth row), we take the first (16-NBC) grid points arranged in ascending order together with the NBC boundary points. This set leads to an array of order 10 x 16. We then determine 10 linearly independent columns giving first preference to the columns corresponding to the boundary conditions. The determination of the linearly independent columns and solution can be carried out simultaneously using a two-dimensional pivot method to insure maximum accuracy.

2.5 Application to the analysis and design phases

The procedure outlined in the previous section is directly applicable to (4) or (9). In the design phase, molecules for $z,_{xx} + z,_{yy}$ and $z,_x$, $z,_y$ are required. In the analysis phase, we need molecules for $z,_{xx}$, $z,_{xy}$, $z,_{yy}$ and $z,_x$, $z,_y$ when the elevation is not expressed as a continuous function. We also need molecules for the second derivatives of F. Since the boundary conditions are identical (both z and F are prescribed on the boundary) the column factors for corresponding second partial derivatives of z and F will be identical and only one computation is requried. We obtain the molecule for (4) by superimposing the molecules for $F,_{xx}$, $F,_{xy}$, and $F,_{yy}$. A program which automates this computation has been developed and is included as a subroutine. The computer first checks whether any points (relative numbers 2-9) are outside the domain. If they are all present, it assembles the difference equation using a standard molecule (e.g., Eq. e). If only one point is missing, it works with 8 grid points. Finally, if 2 or more points are missing, it first assembles the expansions for the boundary points and then determines the molecule.

As an illustration, this procedure was used to determine the molecule for $F,_{xx}$ at point 1 of Figure 5 considering F = 0 on the boundary. The resulting difference equation is listed below.

$$h^2 F_{1,xx} = 5.94 F_1 - 4.7 F_2 + 14.8 F_5 + 1.9 F_7$$

$$+ 10.5 F_9 + 5.1 F_{13} - 3.9 F_{17}$$

3. DESCRIPTION OF THE PROGRAM

3.1 General

This program is written in Fortran II language for an IBM 7094 digital computer. It requires the normal monitor system and utilizes three tapes (logical numbers 10, 11 and 12) for the storage of intermediate results. As it is presented in the listing, the program uses three additional tapes (physical numbers B1, B2 and B3) for storage of the program itself during execution. The usual Fortran chain feature is used to this end. Modification of the chain control cards and call statements would be required to modify the number of tapes used for this purpose.

3.2 Input and sorting of data

Link one of the program is devoted entirely to the reading, sorting and checking of data. It was felt that, since the execution time for a problem is significant, every effort should be made to ensure that the data is consistent before execution begins. The program will give meaningful error codes for the user in the event of an inconsistancy Batches of data may be in any order within themselves although the overall order is of importance. For example, the grid points may be read in any order but the set of grid points cannot be read before the corner points. A complete description of data requirements is given in Appendix B.

In order to prevent one incorrect problem from interfering with the specification of the next problem, starting and ending breaker cards are used. The omission of either of these cards will be interpreted as an error in the formulation of the problem and execution will not take place. The format of these cards is described in Appendix A. The checking of these breaker cards is carried out by Subroutine MATCH (see [7]). The only feature of MATCH which is of interest here is its list searching and comparison capability. MATCH reads a card, prints it and then searches for the first word on the card in an internal dictionary. Arguments are returned which specify whether the word has been found and, if it has, the address of the correspond-

ing word in the dictionary. If the breaker card is found, the data reading process is begun. If not, the card is ignored and another taken. This process is contineud until the first breaker card is found.

Similarly when all the data requirements are satisfied, the last card is examined. If this card satisfied the breaker format, execution is commenced. If the final card is not correct, the program deletes execution and begins looking for the next problem.

Subroutine MATCH is also used to read and interpret the third data card, that is, the problem control card. This card determines which of the three alternatives the user has requested:

1) Analysis using a polynomial to describe the shape of the shell

2) Analysis where the shape is described at discrete grid and boundary points

3) Design of the shape of a shell under a specified loading.

Depending on which procedure is called for by the user, an internal switch (INTSW) is set. This information is then used to branch control at various points during execution.

The program now begins reading and printing the data. The example showin in Figure 6 is used to illustrate this input. First, the program reads the number of sides (NS=3) and number of contours (NC=1). Next connectivity matrix (MCONS) is read in. The only restriction placed on the user is that, for each side, there is one card which specifies the number of that side followed by the numbers of the corner points which the side connects. The connectivity matrix for the example might look like this:

Side No.	Corner Pt.	Corner Pt.
3	8	7
1	8	22
17	22	7

The restriction on the number of sides is set merely from the dimension statement and is at present 100.

This connectivity matrix is rearranged in three steps so that the sides follow each other in a counter clockwise direction around

the perimeter of the shell. The connectivity matrix for the example would be rearranged in the following form:

Side No.	Corner Pt.	Corner Pt.
3	8	7
17	7	22
1	22	8

During this rearrangement, the data is checked for repeated identification numbers and for inconsistency (e.g., the boundary not closing on itself).

The program then reads the numbers and coordinates the corner points (listed below) and calculates the sine and cosine of the angle which each side subtends with the X axis. The limit on the number of corner points is 100.

Corner Pt. No.	Coordinates		
	X	Y	Z
8	0.0	4.0	0.0
7	6.25	0.5	1.8
22	6.25	5.5	0.0

The number of internal grid points (NP=18), the number of loading conditions (NL) and the grid size (H) are read and used to input the list of internal grid points. Each grid point is specified by giving the absolute point number, the height of the mid-surface of the shell at that point (Z) and the vertical loads per unit projected area for that point. If the user has requested that a polynomial be used to specify the shell surface, the coefficients of this polynomial (COE), the power to which it is raised (COE1), and the origin (XORIG, YORIG) about which it is to be used are read in. In this case, the Z value for each grid point is calculated. The list of grid points as read in is listed below. The limit on the number of grid points is 500.

Interior Point Number	Z Height of Shell	Loading At That Point
0401	0.8	1.0
0302	0.9	1.0
0404	1.5	1.0
0405	1.3	1.0

Interior Point Number	Z Height of Shell	Loading At That Point
0405	1.3	1.0
0406	1.2	1.0
0504	0.6	1.0
0505	0.8	1.0
0506	0.6	1.0
0402	1.2	1.0
0403	1.4	1.0
0204	1.2	1.0
0106	1.7	1.0
0303	1.2	1.0
0304	1.4	1.0
0205	1.5	1.0
0206	1.6	1.0
0306	1.4	1.0
0305	1.0	1.0

In order to minimize the width of the band in the difference equations, the internal points are now sorted into a row-wise or column-wise order. The direction of sorting is found by reference to the corner point coordinates. The band width of the final set of difference equations is found and is then used for calculation of the order of the submatrices (MDIM) into which the large band matrix will be broken, For this example, the vertical dimension controls and the points are rearranged in column-wise order.

Interior Point Number	Z Height of Shell	Loading At That Point
0401	0.8	1.0
0302	0.9	1.0
0402	1.2	1.0
0303	1.2	1.0
0403	1.4	1.0
0204	1.2	1.0
0304	1.4	1.0
0404	1.5	1.0
0504	0.6	1.0
0205	1.5	1.0
0305	1.0	1.0
0405	1.3	1.0
0505	0.8	1.0
0106	1.7	1.0
0206	1.6	1.0
0306	1.4	1.0
0406	1.2	1.0
0506	0.6	1.0

The number of boundary points (NBP) is read and then the boundary points themselves. Each point is specified by giving its identification number, the number of the side on which it lies and the X, Y, and Z coordinates of the points. The limit on the number of boundary points is 500.

Boundary Pt. No.	On Side No.	Coordinates X	Y	Z
1	3	2.5	2.5	1.0
2	1	3.0	4.5	1.3
7	17	6.25	2.5	1.5
8	3	4.5	1.5	0.5

The corner points are first added to this list and then the list is sorted so that the points lie in counter clockwise order around the boundary. Note the corner points have been added twice.

Boundary Pt. No.	On Side No.	Coordinates X	Y	Z
0	3	0.0	4.0	0.0
1	3	2.5	2.5	1.0
8	3	3.0	4.8	0.5
0	3	6.25	0.5	1.8
0	17	6.25	0.5	1.8
7	17	6.25	2.5	1.5
0	17	6.25	5.5	0.0
0	1	6.25	5.5	0.0
2	1	3.0	4.5	1.3
0	1	0.0	4.0	0.0

Additional points are then added by the program between the specified boundary points so as, in the final result, no two boundary points lie more than a distance H apart.

Boundary Pt. No.	On Side No.	Coordinates X	Y	Z
0*	3	0.0	4.0	0.0
0	3	.83	3.5	.333
0	3	1.66	3.0	.666
1	3	2.5	2.5	1.0
0	3	3.166	2.83	.83
0	3	3.833	2.166	.66
8	3	4.5	1.5	.5

Boundary Pt. No.	On Side No.	Coordinates X	Y	Z
0	3	5.1	1.83	.96
0*	3	6.25	.5	1.8
0*	17	6.25	.5	1.8
0	17	6.25	1.5	1.65
7	17	6.25	2.5	1.5
0	17	6.25	3.5	1.0
0	17	6.25	4.5	.5
0*	17	6.25	5.5	0.0
0*	1	6.25	5.5	0.0
0	1	5.16	5.16	.43
0	1	4.08	4.83	.86
2	1	3.0	4.5	1.3
0	1	2.0	4.33	.86
0	1	1.0	4.166	.43
0*	1	0.0	4.0	0.0

NB: * denotes original corner points.

If a polynomial has been used to specify the shape of the shell, the value of Z at each boundary point is calculated. The boundary points are checked to ensure that they do in fact lie on the side mentioned.

In the event that an inconsistency has been found in a set of data, the program returns to begin reading a new set of data. Otherwise execution will continue.

3.3 Assemblage of the difference equations

Each grid point is classified into one of three groups by subroutine CLGRID:

1) All of the eight adjacent grid points lie within the shell. The difference equation may be assembled, with sufficient accuracy, by using the classical difference molecules.

2) Only one of the adjacent eight grid points is missing. The difference equation may be assembled with the required accuracy by merely using the remaining seven points.

3) More than one point is missing. Molecules must be calculated using the remaining adjacent grid points, points on the boundary and other internal grid points.

The appropriate number (1, 2, or 3) is placed in the vector LPC to denote the group in which the grid point belongs.

If a point falls in the first group, control branches to instruction 3060. Here the values of Z,xx, Z,xy and Z,yy are calculated either directly from the given polynomial or by applying the classical difference molecules to the given values of Z. These values and again the classical difference molecules for F,xx, F,xy and F,yy are used to assemble the difference equation for the point. The difference equation is then moved into the partitioned difference matrix by making the appropriate entries in the relevant submatrices.

If the point lies in the second group, control will branch to instruction 3075. The Taylor series for the seven remaining adjacent points are found together with that of the grid point itself. These are placed in the coefficient matrix AZ and the absolute numbers of the grid points they represent are stored in KZ. The vector KZ may be thought of then as a vector of unknowns. The Taylor series for the required derivatives are placed into the final columns of AZ so that the matrix AZ becomes an augmented matrix with five right hand sides. Subroutine JUDY is then called and the five solution vectors for the augmented matrix AZ are found. These vectors represent respectively molecules for Z,xx, Z,xy, Z,yy, Z,x and Z,y which satisfy the condition that their use will involve errors only in the fourth and higher derivatives. The first three molecules are also used to find F,xx, F,xy and F,yy. The molecules are back substituted into the original coefficient matrix to ensure that there is no significant error. If an error is detected, a warning is printed. Such a condition can arise where a grid point lies in a very sharp corner of the shell. Such situations seldom arise. These molecules are then used as before to determine the difference equation for the point. Again if a polynomial has been used to describe the shell, the derivatives Z,xx, Z,xy, etc. are found by direct differentiation of this polynomial. The molecules F,xx, F,xy, and F,yy together with the values of Z,x and Z,y are written onto tape 11 for subsequent use in determing the stresses once the stress function has been found (see Part 6.).

When a grid point lies in the third group, the boundary condition is assembled at points along the boundary. The number of such points depends on the distance to the boundary from the grid point. Subroutine DIST is called for each side making up the boundary. If the distance from the grid point to any side is less than $H\sqrt{2}$, (H=Gridsize), the closest point on that side is found. This point is checked to make certain it does in fact lie on the boundary, and then the Taylor series representing the point is found. This Taylor series is moved into the AZ matrix and its column address is stored in KZ. Subroutine FINDZD is called and returns the value of Z at that point by interpolation between the boundary points read in during Part 1. The program re-examines the distance to the side. If it is also less than the gridsize (H), then the same procedure is followed for two additional points lying a distance H away along the boundary. When every side has been examined, the Taylor series for the surrounding grid points (relative numbers $2 \rightarrow 25$) are assembled. Any point lying outside the shell is neglected. The Taylor series for the derivatives are moved into the final columns of AZ and Subroutine JUDY is called on the augmented matrix AZ. This subroutine finds the first 10 linearly independent columns giving preference to the boundary conditions and then to the closest surrounding grid points. The molecules for the required derivatives are found using these first 10 columns and the program proceeds, as for a group 2 point, to assemble the difference equation.

When a row of sub-matrices of the difference equations matrix has been fully assembled (i.e., when a number of grid points equal to the order of the sub-matrices has been treated) the three submatrices are written onto tape and the sub-matrices cleared for the next group of grid points.

When every grid points has been treated, the final row of sub-matrices is completed by setting the diagonal element of the diagonal sub-matrix equal to 1 and the corresponding right hand member equal to 0. This merely ensures that all of the sub-matrices are square and of the same order, and so no problems of conformability will arise during solution.

3.4 Solution of difference equations

The difference equation are now solved by Gauss elimination on sub-matrices. At this point, the program has assembled all the difference equations and has them stored on tapes 10 and 12 in sub-matrix form. Figure 7 shows the partitioned form of the equations. The null matrices 1 and 9 have been also written on tape to facilitate the iterative procedure. At any time, only three sub-matrices are required in core. These are denoted as A1, A2, and A3. At first, both A1 and A3 are strictly triangular but do not necessarily remain so throughout the solution procedure. As each row of sub-matrices is treated, the modified matrix A3 is written onto tape 11 to be used later in the back sweep. The diagonal sub-matrix A2 is inverted using pivotal condensation and double precision arithmetic.

The solution is stored over the original loadings in Q. This solution is back substituted into the original coefficient matrix to gain some indication of the errors involved. If the errors are not acceptable, the difference equations are re-solved using the errors as the right hand members. This solution is added to the old solution, and the sum is back substituted into the coefficient matrix. Again the error is examined. This iteration is continued until a satisfactory solution has been found. For this purpose, an acceptable error is defined by the following conditions:

$$\text{Acceptable error at point} \quad < \quad \text{loading at that point} \quad \times \quad 10^{-6}$$

For every case so far tested, this procedure has not been necessary, as the first attempt at solution yields errors which are at least 7 orders of magnitude less than the solution. It is possible however that a case may arise which requires such iteration.

It may also be of interest to mention that, during testing of the program, we forced at least one cycle of back substitution and interation on the error. However, this did not change the solution in any detectable way, and we conclude that the difference equations strongly suggest a unique solution for each of the cases that were tested. These cases include those given in the section on camparison of results.

3.5 Boundary points

The boundary points are now treated to calculate molecules for F,xx, F,xy and F,yy, and for Z,x and Z,y. These molecules are used to find the stresses acting at each boundary point.

The program first finds the closest internal grid point to the boundary point in question. Then the boundary condition, F=0, is assembled as a Taylor series in the AZ matrix. This is done first for the boundary point itself and then for adjacent points a distance H away along the boundary. The program then goes through each of the grid points of relative number 1 through 25 (relative to the closest grid point). If the point lies inside the domain of the shell, the Taylor series for that grid point written about the boundary point is found and moved into the AZ matrix.

The Taylor series for the desired derivatives are written into the last columns of the augmented AZ matrix and subroutine JUDY is called. As before, this subroutine finds the first 10 linearly independent columns giving preference to the boundary conditions and then to the closer grid points. The molecules for the desired derivatives are found using these 10 linearly independent columns and are written onto tape 12. When each boundary point has been treated, the program continues with the next phase.

3.6 Back substitution and output

At this point in the program, the stress function has been found at each grid point. Molecules for the derivatives at each grid point and each boundary point are written on tapes 11 and 12 respectively together with the values of Z,x and Z,y necessary to find the actual stress resultants on the shell from the projected stress resultants.

These molecules are now read back into core and applied to the values of F at the appropriate grid points and boundary points (F=0 for boundary points). This procedure yields the values of F,xx, F,xy and F,yy which represent the values of the projected stress resultants $\overline{N}yy$, $\overline{N}xy$, and $\overline{N}xx$. Using the values of Z,x and Z,y previously calculated, the stress resultants and principal stress resultants are found and printed.

In the design phase, the procedure is analogous. The values of $\bar{N}xx$, $\bar{N}xy$, and $\bar{N}yy$ have been read in during Part 1. The actual shape of the shell has been solved for and is now stored in Q. (The shape is specified discretely at the grid points.) The values of Z,x and Z,y are found from the molecules previously computed in Parts 2 and 5. The values of Z at the various boundary points used in these molecules have been found and multiplied into the molecules in Parts 2 and 5 of the program. Using this information the stress resultants and boundary forces are found and printed out. The program then returns to Part 1 and commences reading the next set of data.

3.7 Required computation time

The program is at present in I.B.M. 7094 version and the following times refer to this computer and the M.I.T. Fortran Monitor System.

To compile the entire program from Fortran source decks - 10 minutes.

To set up the chain, linkages, etc. from binary decks - 3.2 minutes.

Solution of a problem involving about 50 gridpoints - 40 seconds.

Solution of a problem involving about 80 gridpoints - 80 seconds.

Solution of a problem involving about 220 gridpoints - 230 seconds.

If we denote the number of gridpoints by N and define B by the following equation

$$B = (\text{total length of boundary})/\ \text{gridsize}$$

then the time for execution in seconds is given by the relation

$$T = .0025\ N^2 + .365\ N + .565\ B$$

4. DISCUSSION OF RESULTS

The method was tested by applying the program to cases for which the exact membrane solution is available. Two such examples are presented here:

1. The case of a parabola of revolution on a triangular base. The exact solution for this case is given in Novoshilov [1].

2. The case of an elliptic parabola on a square base. This case is treated in Billington [6].

The first example presents no problems as the exact solution is well behaved. Table 1 and Figure 8 present the comparison of the computed stress resultants with those given by the exact solution. There is virtually no difference between the two sets of values.

The second example was a much more severe test since, in the exact solution, the shear stresses are infinite at the corners. The computed stress resultants are compared with the exact solution in Table 2 and Figure 9. It is interesting to note that the error in the shear stresses at the corners is not propagated throughout the entire solution, and that the reduction of the grid size from 1.0 to 0.5 forces this error further into the corners.

Two examples of the design phase are presented in Table 3 and in Figure 10. Both cases have the same prescribed boundaries and both are subjected to a uniform projected load. However, in the first example, the prescribed stress resultants are compressive while in the second case, they are tensile.

The shells developed by the design phase require certain boundary forces, and unless these forces are supplied, the prescribed stress state will not exist throughout the shell. However the developed shapes are interesting and may be of help to the designer in arriving at an initial shell shape.

The membrane solution of a shell with the boundary condition $F = 0$ is by no means the only information necessary for the design of a shell structure. However the membrane solution is usually of great value to the engineer and is the logical place to begin the analysis in many cases. This program is an extremely useful tool for this purpose particularly in cases of unusual shell geometry.

PROJECTED STRESS RESULTANTS

Point	(COMPUTER) $\bar{N}_{xx}$	$\bar{N}_{yy}$	$\bar{N}_{xy}$	(EXACT) $\bar{N}_{xx}$	$\bar{N}_{yy}$	$\bar{N}_{xy}$
1	-4.68	-.323	3.23	-4.68	-.321	3.23
2	-4.68	-.323	1.94	-4.68	-.321	1.94
3	-4.67	-.323	.645	-4.68	-.321	.645
4	-4.68	-.323	0	-4.68	-.321	0
5	-4.03	-.968	1.94	-4.03	-.968	1.94
6	-3.39	-1.61	.645	-3.39	-1.61	.646
7	-2.5	-2.5	0	-2.5	-2.5	0

TABLE 1

EXAMPLE - PARABOLA OF REVOLUTION

SEE FIGURE 8

PROJECTED STRESS RESULTANTS

Pt.	Gridsize = 1.0			Gridsize = .5			Exact Solution		
	$\bar{N}_{xx}$	$\bar{N}_{xy}$	$\bar{N}_{yy}$	$\bar{N}_{xx}$	$\bar{N}_{xy}$	$\bar{N}_{yy}$	$\bar{N}_{xx}$	$\bar{N}_{xy}$	$\bar{N}_{yy}$
1				.53	1.03	.43	.57	-*	.41
2				.78	.87	.28	.88	.81	.23
3				.91	.66	.20	.94	.62	.18
4				.98	.49	.16	1.00	.47	.15
5				1.02	.35	.14	1.02	.34	.14
6				1.05	.23	.12	1.05	.22	.12
7				1.06	.11	.11	1.06	.11	.11
8				1.06	.00	.11	1.07	0.00	.10
9	.52	.60	.44	.51	.66	.44	.51	.66	.44
10				.66	.54	.35	.66	.54	.35
11	.75	.44	.30	.76	.42	.30	.76	.42	.30
12				.82	.30	.26	.82	.30	.26
13	.86	.21	.24	.86	.20	.23	.86	.20	.23
14				.88	.10	.22	.88	.10	.22
15	.89	.01	.22	.89	0.00	.22	.89	0.00	.21
16				.49	.42	.45	.49	.42	.45
17				.59	.33	.40	.59	.33	.40
18				.66	.25	.35	.66	.25	.35
19				.71	.16	.33	.71	.16	.33
20				.73	.08	.31	.73	.08	.31
21				.74	0.00	.31	.74	.00	.31
22	.48	.25	.46	.47	.25	.47	.47	.25	.47
23				.54	.19	.43	.54	.19	.43
24	.58	.13	.40	.58	.13	.40	.58	.13	.40
25				.61	.06	.38	.61	.06	.38
26	.62	.00	.38	.62	.00	.38	.62	.00	.38
27				.45	.14	.48	.45	.14	.48
28				.49	.09	.45	.49	.09	.45
29				.52	.05	.44	.52	.05	.44
30				.53	.00	.43	.53	.00	.43
31	.43	.06	.49	.43	.06	.49	.43	.06	.49
32				.45	.03	.48	.45	.03	.48
33	.46	.00	.47	.46	.00	.47	.46	.00	.47
34				.42	.02	.50	.42	.02	.50
35				.42	.00	.50	.42	.00	.50
36	.42	.00	.50	.41	.00	.50	.41	.00	.50

*The interpolation for this stress resultant involves a term = ∞

TABLE 2 -- EXAMPLE - ELLIPTICAL PARABOLOID -- SEE FIGURE 9

Gridsize = 1.0

Height of shell at the boundary is defined by:

$$Z(X,Y) = -.75X^2 - .75Y^2 + 2.4$$

Pt. No.	Height of Shell Tensile Case	Height of Shell Compressive Case	Pt. No.	Height of Shell Tensile Case	Height of Shell Compressive Case
1	.44	.52	27	.78	1.29
2	.74	.90	28	1.02	1.23
3	.95	1.14	29	.95	1.14
4	1.02	1.23	30	.76	1.23
5	.95	1.14	31	.70	1.32
6	.74	.90	32	.69	1.35
7	.44	.52	33	.70	1.32
8	.74	.90	34	.76	1.23
9	.73	1.09	35	.95	1.14
10	.76	1.23	36	.74	.90
11	.78	1.29	37	.73	1.09
12	.76	1.23	38	.76	1.23
13	.73	1.09	39	.78	1.29
14	.74	.90	40	.76	1.23
15	.95	1.14	41	.73	1.09
16	.76	1.23	42	.74	.90
17	.70	1.32	43	.44	.52
18	.69	1.35	44	.74	.90
19	.70	1.32	45	.95	1.14
20	.76	1.23	46	1.02	1.23
21	.95	1.14	47	.95	1.14
22	1.02	1.23	48	.74	.90
23	.78	1.29	49	.44	.52
24	.69	1.35			
25	.66	1.37			
26	.69	1.35			

TABLE 3

EXAMPLE - DESIGN PHASE

See Figure 10

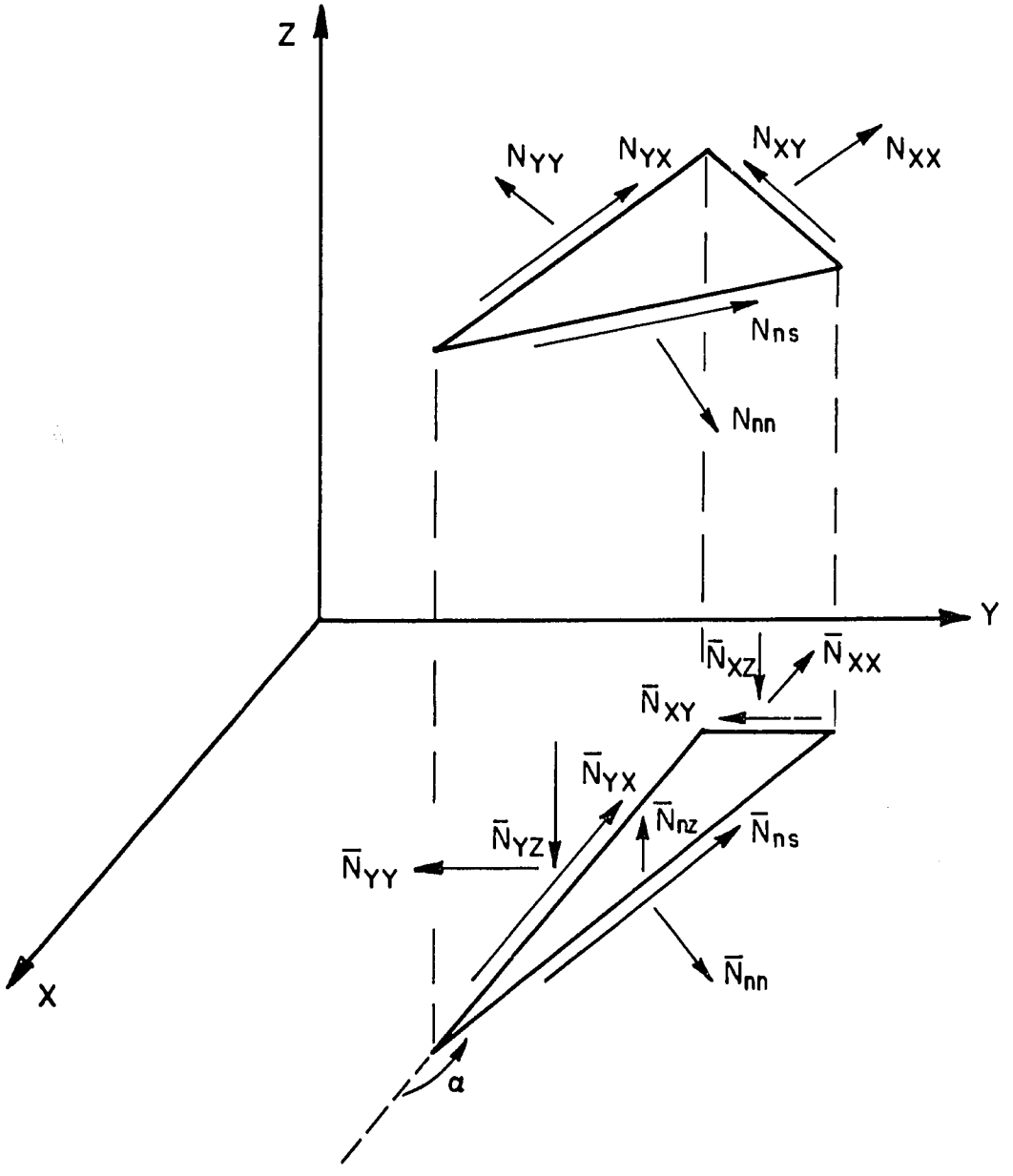


FIGURE I

ACTUAL AND PROJECTED STRESS RESULTANTS

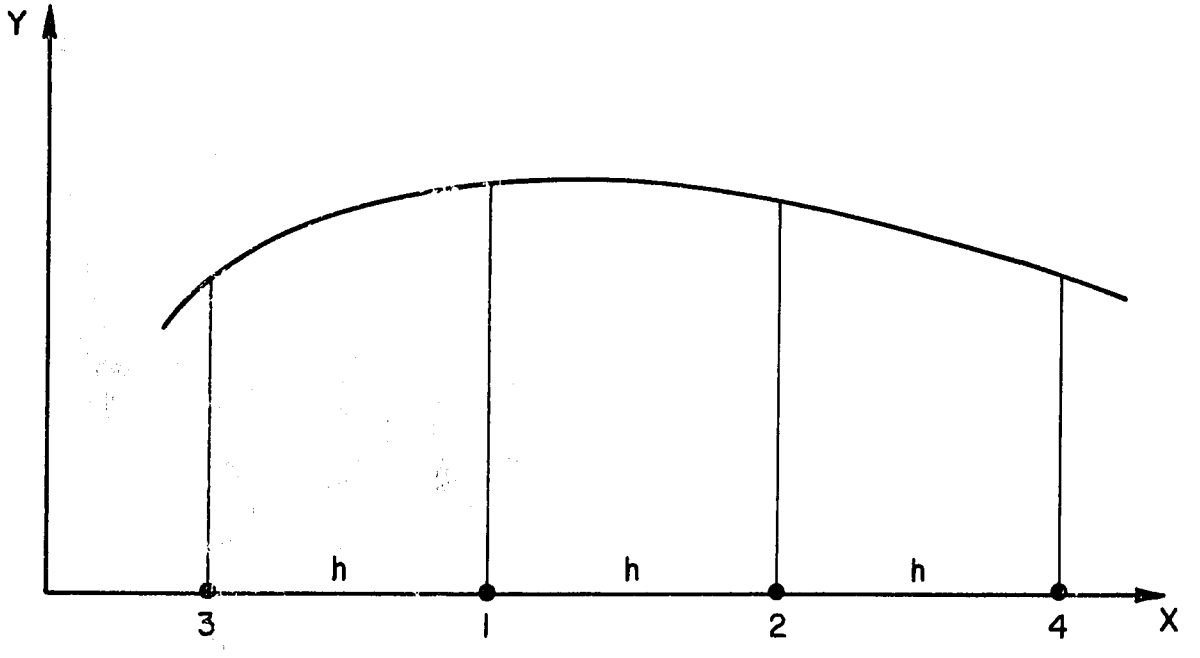


FIGURE 2

RELATIVE NUMBERING SCHEME

(One-dimensional case)

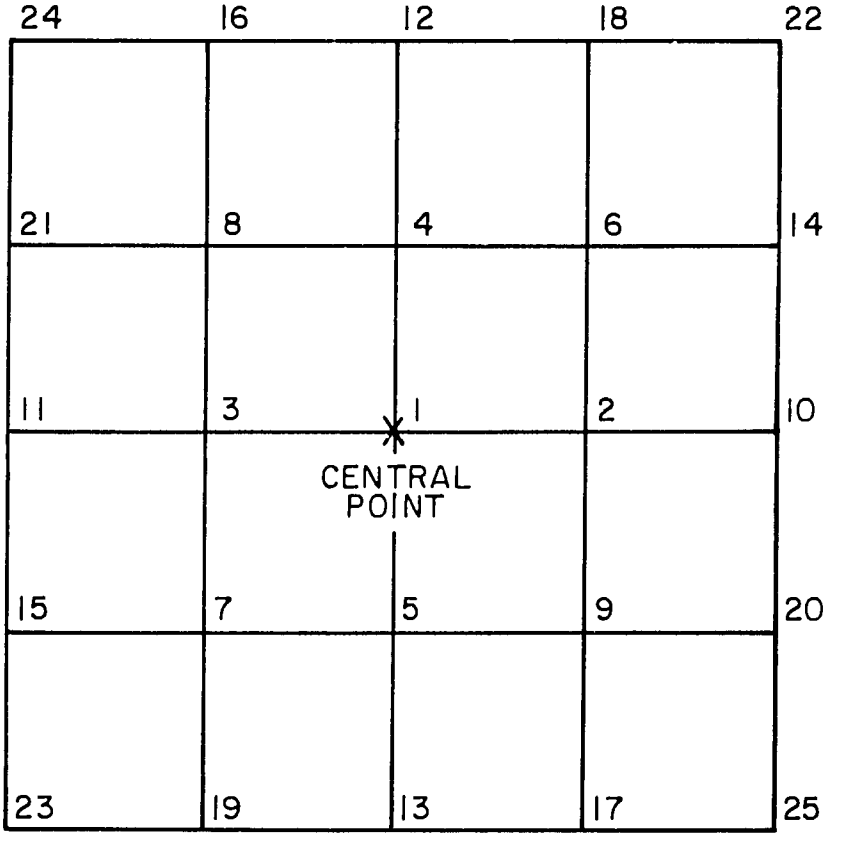


FIGURE 3
RELATIVE NUMBERING SCHEME
(Two - dimensional case)

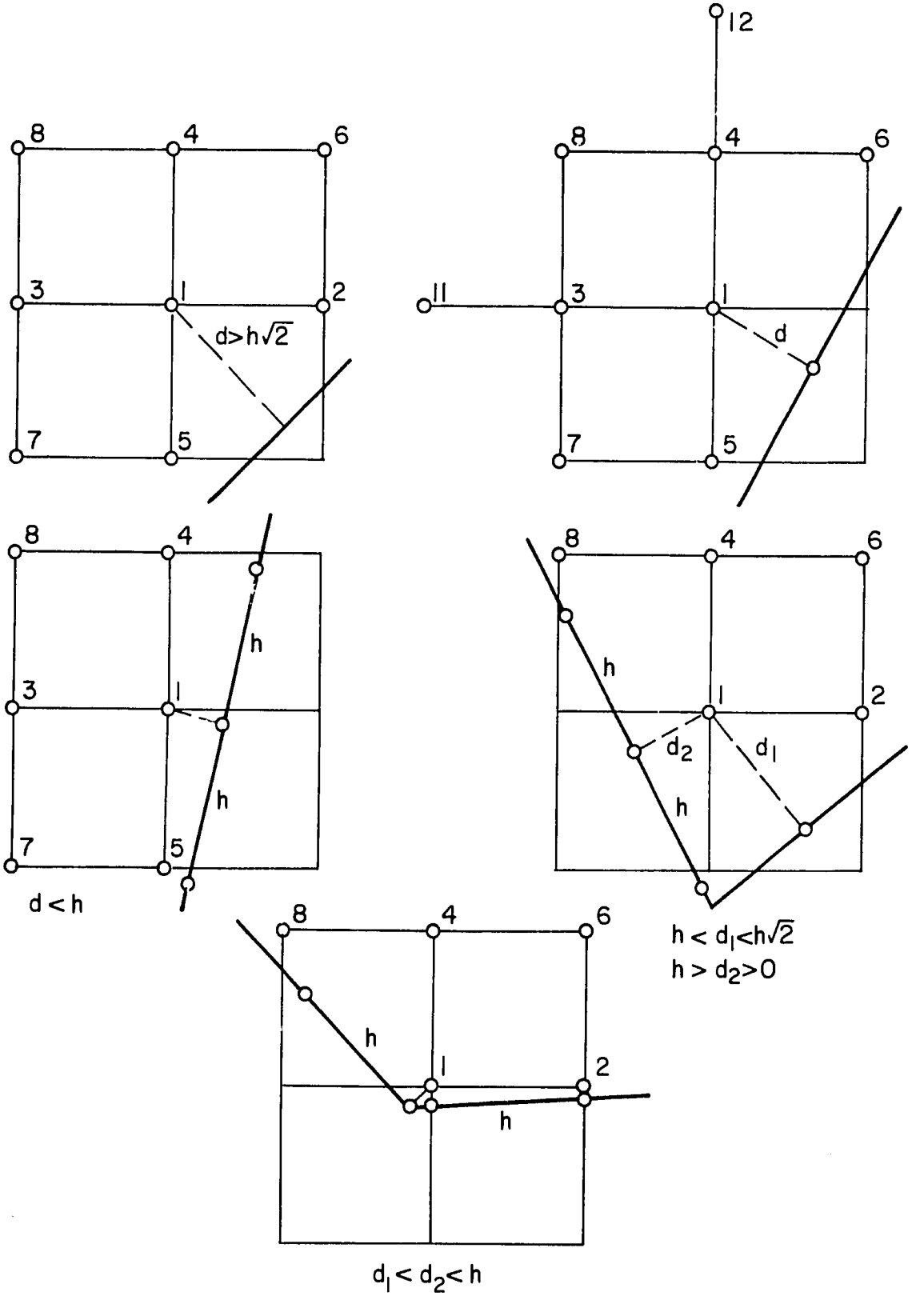
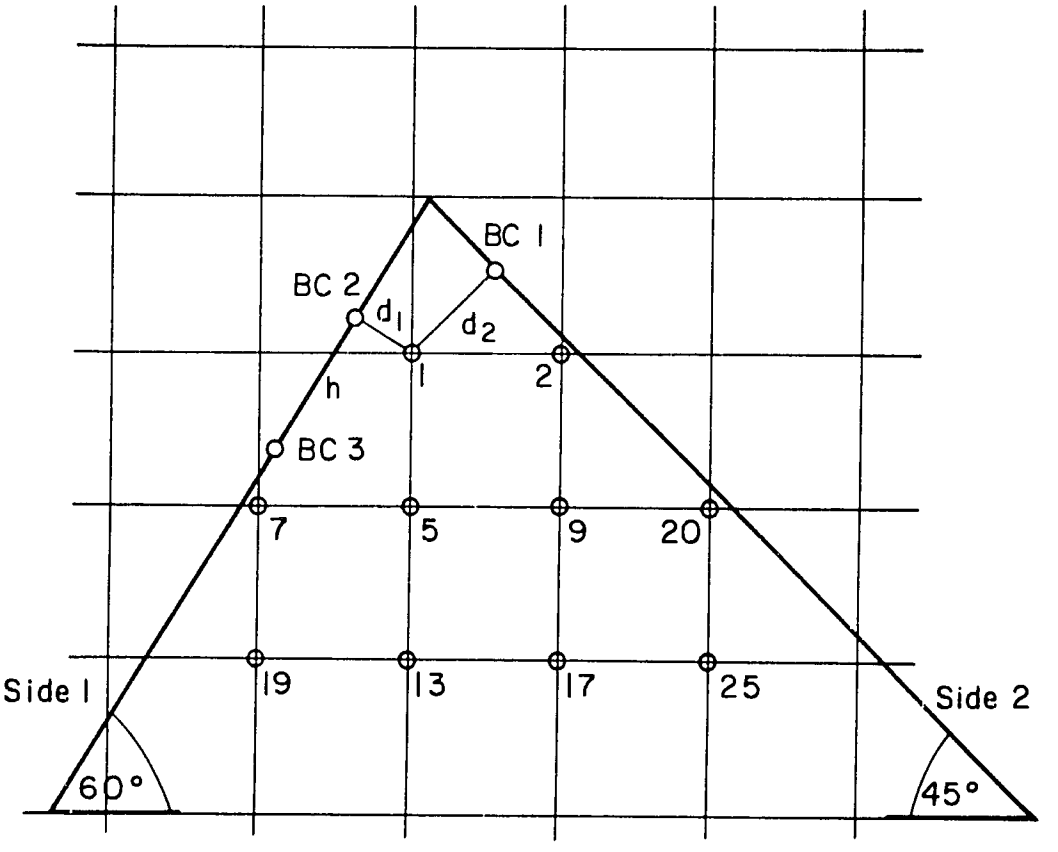


FIGURE 4
INCLUSION OF BOUNDARY CONDITIONS



$$d_1 < h$$

$$h < d_2 < h\sqrt{2}$$

FIGURE 5

ILLUSTRATIVE EXAMPLE

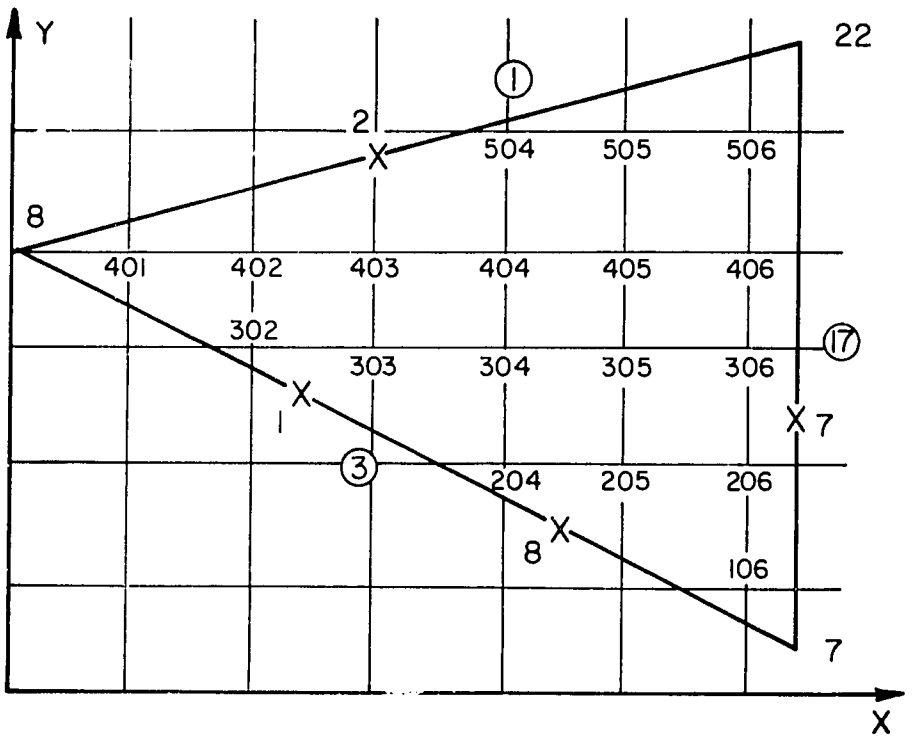


FIGURE 6
ILLUSTRATIVE EXAMPLE - BOUNDARY INPUT

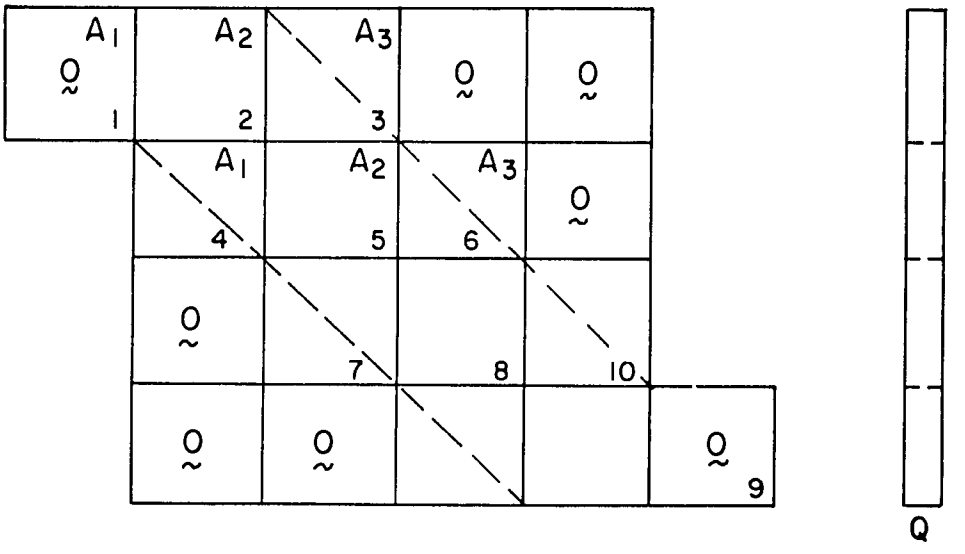
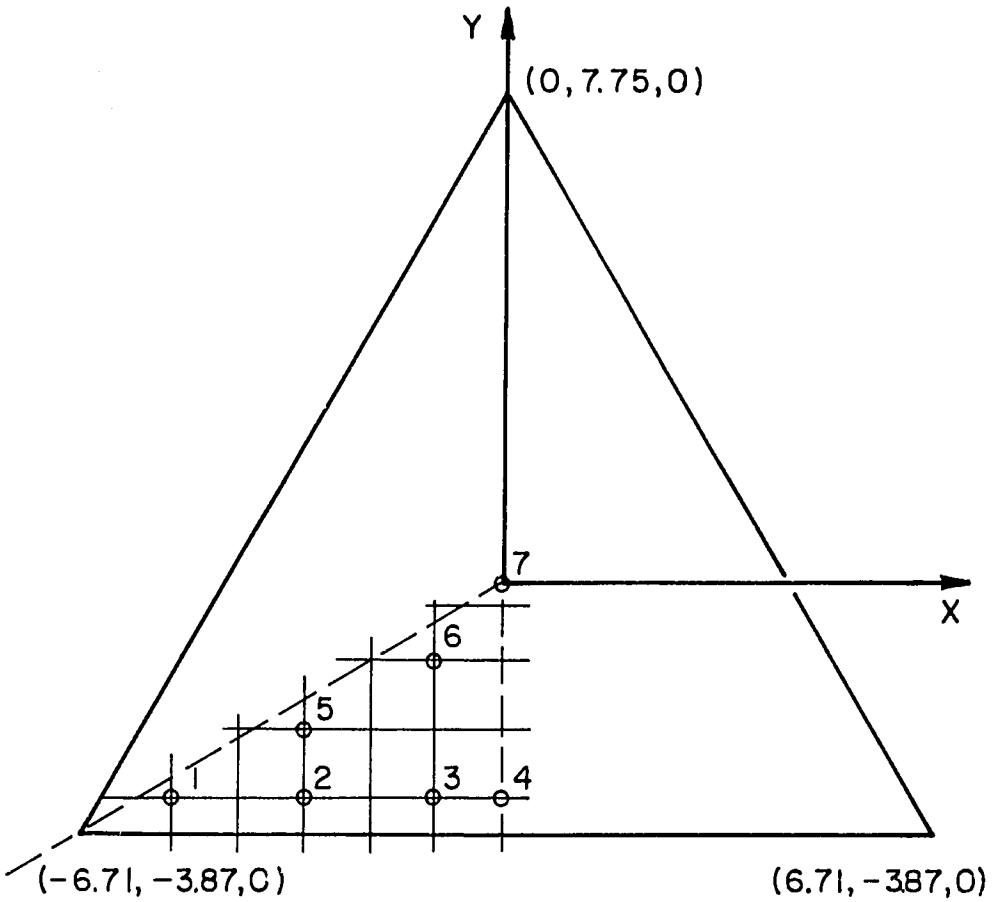


FIGURE 7
PARTITIONED FORM OF THE DIFFERENCE EQUATIONS



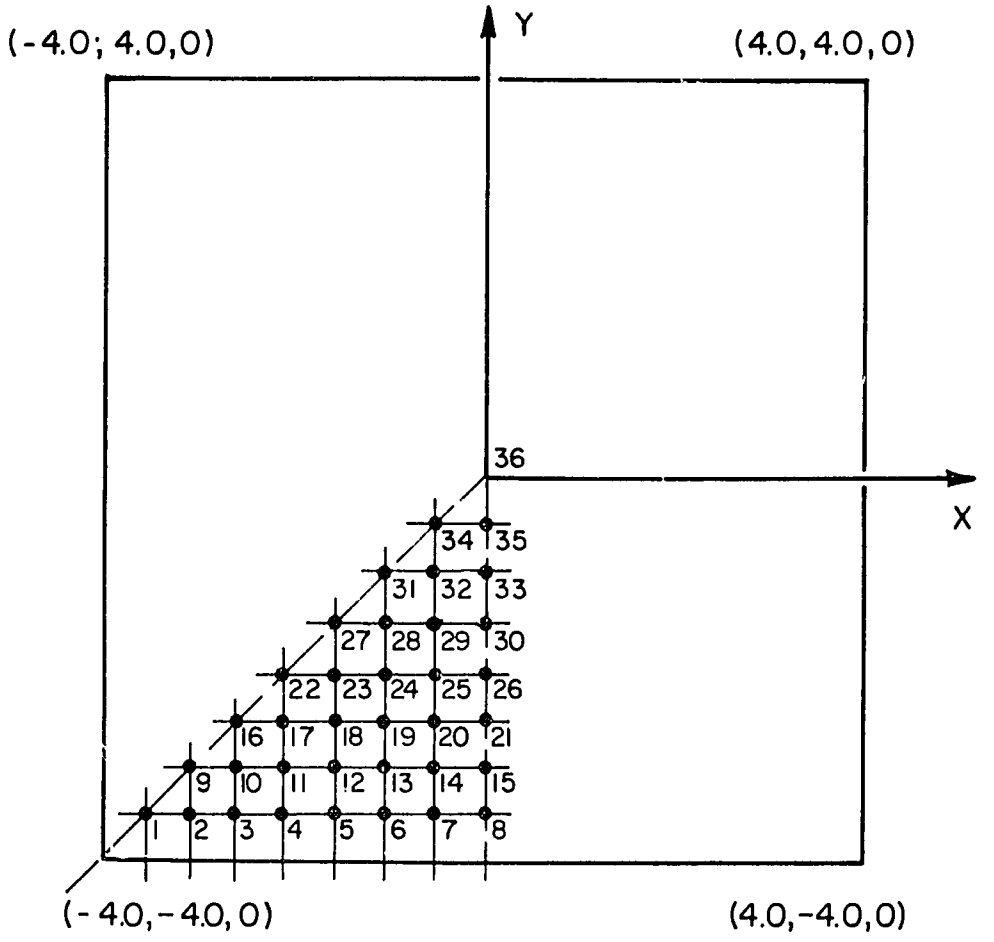
$$Z = -.1X^2 - .1Y^2 + 6$$

GRIDSIZE = 1.0

$\bar{P}_Z(X,Y) = -1.0$

FIGURE 8

EXAMPLE - PARABOLOID OF REVOLUTION

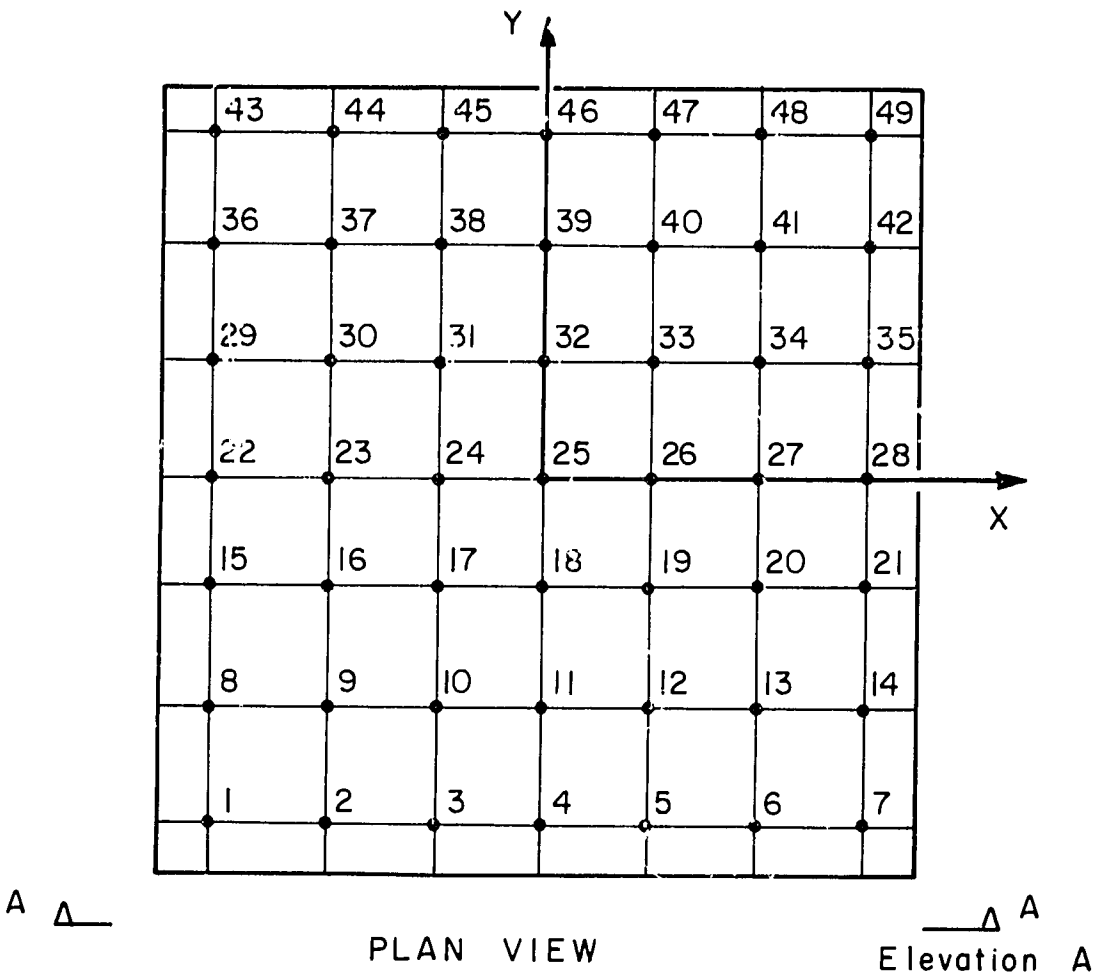


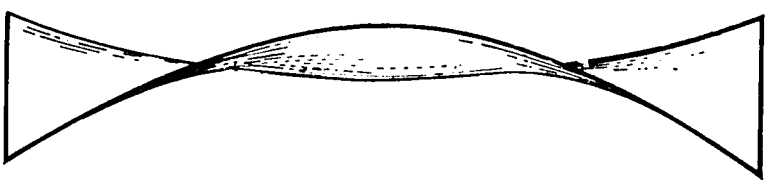
$$Z = -.1X^2 - .167Y^2 + 4.27$$

GRIDSIZE = .5

$\bar{P}_Z(X,Y) = -1.0$

FIGURE 9
EXAMPLE - ELLIPTICAL PARABOLOID





ELEVATION A
TENSILE CASE

ELEVATION A
COMPRESSIVE CASE

FIGURE 10
EXAMPLE DESIGN PHASE – SEE TABLE 3

REFERENCES

(1) Novoshilov, V. V.: "Thin Shell Theory," Nordhoff, Ltd., Groningen, 1964.

(2) Pucher, A.: "Uber den Spannungszustand in Gekrummten Flachen," Beton und Eisen, Vol. 33, page 298, 1934.

(3) Collatz, L.: "The Numerical Treatment of Differential Equations," Springer-Verlag, Berlin, 1959.

(4) Engeli, M.: "Automatisierte Behandlung Elliptischer Randwert-probleme," Ph.D. Thesis, E.T.H., 1962.

(5) Wolf, J. P.: "Automatic Treatment of Pucher's Equation," S.M. Thesis, M.I.T., June, 1965.

(6) Billington, D. P.: "Thin Shell Concrete Structures," McGraw-Hill, New York, 1965.

(7) Fenves, S. J., Logcher, R. D., Mauch, S.: "Stress Reference Manual," M.I.T. Press, Cambridge, 1964.

APPENDIX A

DATA AND ERROR CODES

This program checks the data, as far as it is possible, to ensure that there are no contradictions. If some mistake is discovered in the data either in Part 1 or at some later phase of the execution, an error code which will have some meaning to the user is printed out. Thus the program should never merely stop at some point without giving some reason why difficulty was encountered.

If a contradiction in the data is discovered in Part 1, the program will continue to read the data to check for additional errors. In some cases, however, only the first error code will be meaningful. For example, the number of sides as read in is used as an index to read in other parcels of data -- the connectivity matrix and the corner point numbers and coordinates. If a mistake is made in specifying the number of sides, only part of the connectivity matrix will be read in, and so error codes will result concerning this connectivity matrix. These later error codes may be without foundation.

I6 and F12.4 formats are used throughout for reading data. The normal Fortran rules apply to the preparation and punching of data cards.

<u>Format of Data</u>

	Column 1 2
First Card	SHELL PROBLEM
Second Card	PROBLEM NAME OR TITLE
Third Card (one of these)	ANALYSIS USING A FUNCTION TO SPECIFY THE SHELL SURFACE ANALYSIS SPECIFYING THE SURFACE AT DISCRETE POINTS DESIGN A SHELL UNDER THE SPECIFIED CONDITIONS
Fourth Card	3 1

where 3 is a fixed point number specifying the number of sides and 1 is a fixed point number specifying the number of boundaries

Fifth Card 17 22 16

where 17, 22, and 16 are all fixed point numbers
17 is the side number
22 and 16 are the corner point numbers which side number 17 connects
There will be one card of this type for each side.

Next Cards 22 15.1 18.2 3.2

where 22 is a fixed point corner point number
15.1 is the X coordinate of the corner point
18.2 is the Y coordinate of the corner point
3.9 is the Z coordinate of the corner point.
There will be one card of this type for each corner point.

Next Card 47 1

where 47 and 1 are fixed point numbers
47 is the number of internal grid points
1 is the number of loading conditions.

Next Card .75

where .75 is the size of the grid spacing.

Next Cards 0203 2.37 1.8

where 0203 is a fixed point number which corresponds to a grid point. The first two digits specify the Y coordinate of the point in multiples of the grid size. The second two digits specify the X coordinate in multiples of the grid size about the origin. For example, the point number 1703 with a grid size of .5 specifies an internal point with coordinates Y=8.5, X=1.5.

2.37 is a fixed point number and specifies the ehight of the shell above the X Y plane at this point. This variable is positive upwards.

1.8 is the vertical load on this area of the shell if the area were projected on to the X Y plane. This variable is positive downwards.

Only grid points which lie inside the boundary of the shell are to be specified. There must be one such card for each grid point.

If a function is to be used to specify the Z coordinate, or if design of a surface is called for, the Z field must be left blank.

If a shell is described by a function, the next 12 cards are used to specify this function. The function available is:

$$Z = (C_1Y^3 + C_2Y^2X + C_3YX^2 + C_4X^3 + C_5Y^2 + C_6XY + C_7X^2 + C_8Y + C_9X + C_{10})^c$$

Each coefficient, C_1 through C_{10} must be on a separate card and punched in floating point before column 13. Any coefficient may be zero.

The eleventh card specifies the coefficient "c" -- the power to which the entire function is raised. At present "c" may only have values of .5 and 1.0.

The twelfth card specifies the origin about which the polynomial is to be taken. Two floating point numbers, X and Y, are punched.

X is the coordinate of the origin of the polynomial about the origin (0,0). Y is Y coordinate of the origin of the polynomial.

These twelve cards are omitted in the cases of the shell surface being specified at points or by design.

If design has been called for, a card is placed here which specifies the value of the second derivatives of the stress function with respect to X and Y. The value is punched before column 13 in floating point form.

Next Card 22

where 22 is the number of boundary points.

Next Cards 7 3 7.1 8.7 1.2

where 7 and 3 are fixed point numbers.
7 is the identification number of the boundary point
3 is the side number on which the boundary point lies

7.1, 8.7 and 1.2 are the X, Y, and Z coordinates of the point.

The boundary points may be read in in any order. Corner points should not be included as they are added automatically by the program. The program will also add additional points between the specified boundary points if any two lie a greater distance apart than the gridsize. The identification number 0 is assigned to such points.

Last Card PROBLEM SPECIFIED

This card is merely a breaker card and informs the program that the data is complete.

A sample set of data follows for the shell as drawn on Page

APPENDIX B -- EXAMPLE OF A SET OF DATA

There follows a set of data for the shell illustrated in Figure 6. We shall assume that analysis of this shell is required, and that the shell surface is described at discrete grid points.

```
SHELL PROBLEM
TITLE:  DATA EXAMPLE
ANALYSIS SPECIFYING THE SURFACE AT DISCRETE POINTS

      3
      3        8        7
      1        8       22
     17       22        7
      8        0.0                4.0          0.0
      7        6.25               0.5          1.8
     22        6.25               5.5          0.0
     18        1
         1.0
   0401        0.8            1.0
   0302        0.9            1.0
   0404        1.5            1.0
   0405        1.3            1.0
   0406        1.2            1.0
   0504        0.6            1.0
   0505        0.8            1.0
   0506        0.6            1.0
   0402        1.2            1.0
   0403        1.4            1.0
   0204        1.2            1.0
   0106        1.7            1.0
   0303        1.2            1.0
   0304        1.4            1.0
   0205        1.5            1.0
   0206        1.6            1.0
```

0306	1.4	1.0		
0305	1.0	1.0		
4				
1	3	2.5	2.5	1.0
2	1	3.0	4.5	1.3
7	17	6.25	2.5	1.5
8	3	4.5	1.5	0.5

PROBLEM SPECIFIED

Appendix C

LIST OF SYMBOLS

AZ	matrix containing Taylor expansions of grid and boundary points. This matrix is solved to give the molecules for $F,_{xx}$, $F,_{xy}$ and $F,_{yy}$; $z,_{xx}$, $z,_{xy}$, $z,_{yy}$, $z,_{x}$ and $z,_{y}$
A1, A2, A3	Submatrices of the band matrix of difference equations
ALFA or α	x direction parameter in Taylor series expansion
AN or $\bar{N}$	allowable projected stress resultant in design phase
BETA or β	y direction parameter in Taylor series expansion
COSS	values of cosine of the angle between a side and the x axis
COE	the coefficients of the polynomial used to specify the shell surface
COE1	the power to which this polynomial is raised (1 or .5)
CPC	the matrix of corner point coordinates
D or d	the least distance from the central grid point to a side
DEGB	the angle that the principal stress resultants make with the x axis in degrees
H or h	grid size
IEXQ	an internal pointer. When set to 1, the program will delete execution after reading data
INEXT	a pointer which deletes the search for the initial breaker card in a set of data in the event that this card has already been read with the previous set of data
INTSW	an internal pointer which is used to branch control where the phases of execution differ
IMID	the final number of boundary points after additional points have been added by the program

IPRINT	controls the printing of intermediate output and is set in Part 0
KF KSTAR	the list of points to which the current molecule refers
KZ	the list of grid points to which the columns of AZ refer, and later, to which the molecules refer
KZBP	column exchange vector z-phase in points on boundary
LBP	list of boundary points
LBPS	list of boundary points per side
LP	list of grid points
LPC	list of grid points classification
LX	the current number of solution iterations
$\bar{N}_{xx}$, $\bar{N}_{xy}$, $\bar{N}_{yy}$	projected stress resultants (Fig. 1)
N_{xx}, N_{xy}, N_{yy}	stress resultants
$\bar{N}_{nn}$, $\bar{N}_{ns}$, $\bar{N}_{nz}$	projected boundary forces
NBC	number of boundary conditions formulated
NBP	number of points on boundary
NC	number of contours
NL	number of loadings
NP	number of grid points
NS	number of sides
NSC	number of sides per contour
MCONS	connectivity matrix
MDIM	number of grid points along smaller side of enclosing rectangle
MC	vector of corner point numbers
$\bar{P}_z$	vertical load per projected unit area
Q	vertical load per projected unit area in every grid point and for every loading
R	submatrix of R.H.S. in solution
RDE	difference equation for Pucher's equation
RFXX	difference equation for $F,_{xx}$ in grid point
RFXXBP	difference equation for $F,_{xx}$ in point on boundary

RFXY	difference equation for $F,_{xy}$ in grid point
RFXYBP	difference equation for $F,_{xy}$ in point on boundary
RFYY	difference equation for $F,_{yy}$ in grid point
RFYYBP	difference equation for $F,_{yy}$ in point on boundary
SINS	sin of angle between y-axis and side (counterclockwise)
SN1, SN2	principal stress resultants
SNXX	N_{xx}
SNXY	N_{xy}
SNYY	N_{yy}
SNNS	$\bar{N}_{ns}$
SNNZ	$\bar{N}_{nz}$
TITLE	the title of the problem
TSF	Taylor series expansion for F
XBP	x-coordinate of points on boundary
XD	x-coordinates of point on side where boundary conditions are formulated
XORIG	the x origin for the polynomial which describes the shell surface
YBP	y-coordinate of points on boundary
YD	y-coordinate of points on side where boundary conditions are formulated
YORIG	the y origin for the polynomial which describes the shell surface
Z	elevation of midsurface in all grid points
ZBC	vector containing z-values on the boundary used in difference equation
ZBP	z-coordinate of points on boundary
ZD	z-coordinate of point on side where boundary conditions are formulated
ZXBP(NBPE)	$z,_x$ in extended points on boundary
ZX	$z,_x$ in grid point
ZY	$z,_y$ in grid point

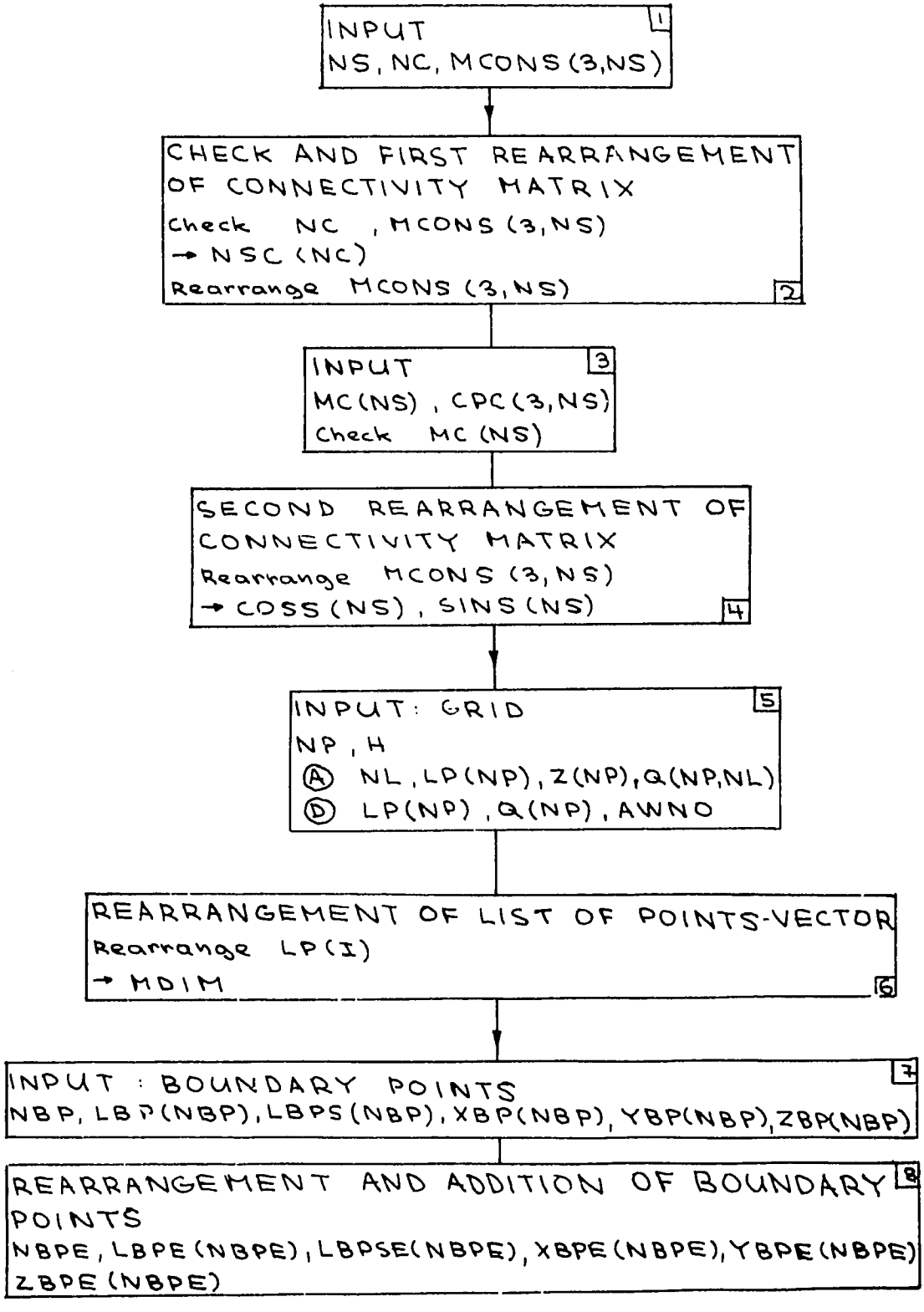
ZXX	$z_{,xx}$
ZXY	$z_{,xy}$
ZYY	$z_{,yy}$

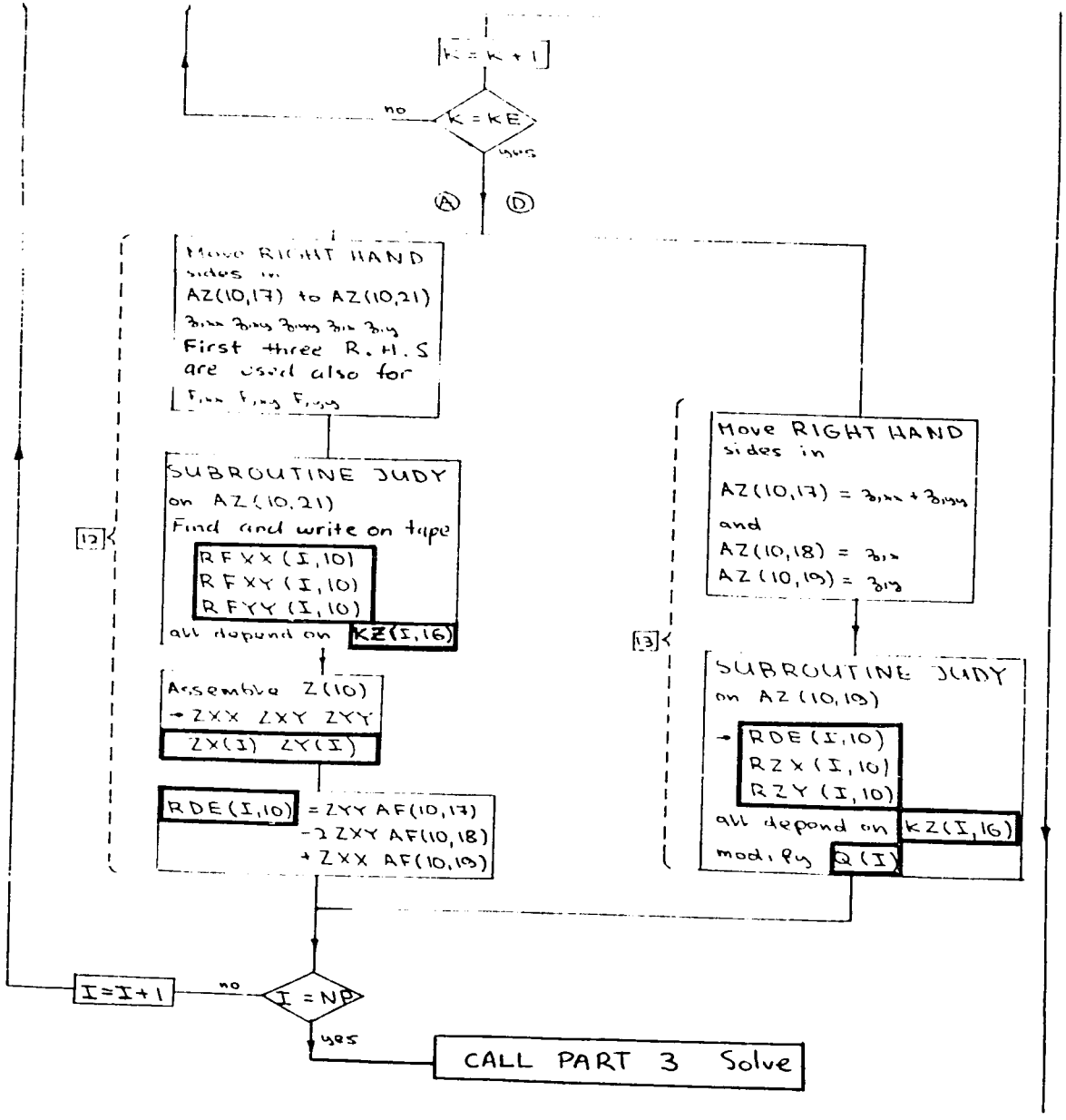
APPENDIX D -- FLOW CHARTS

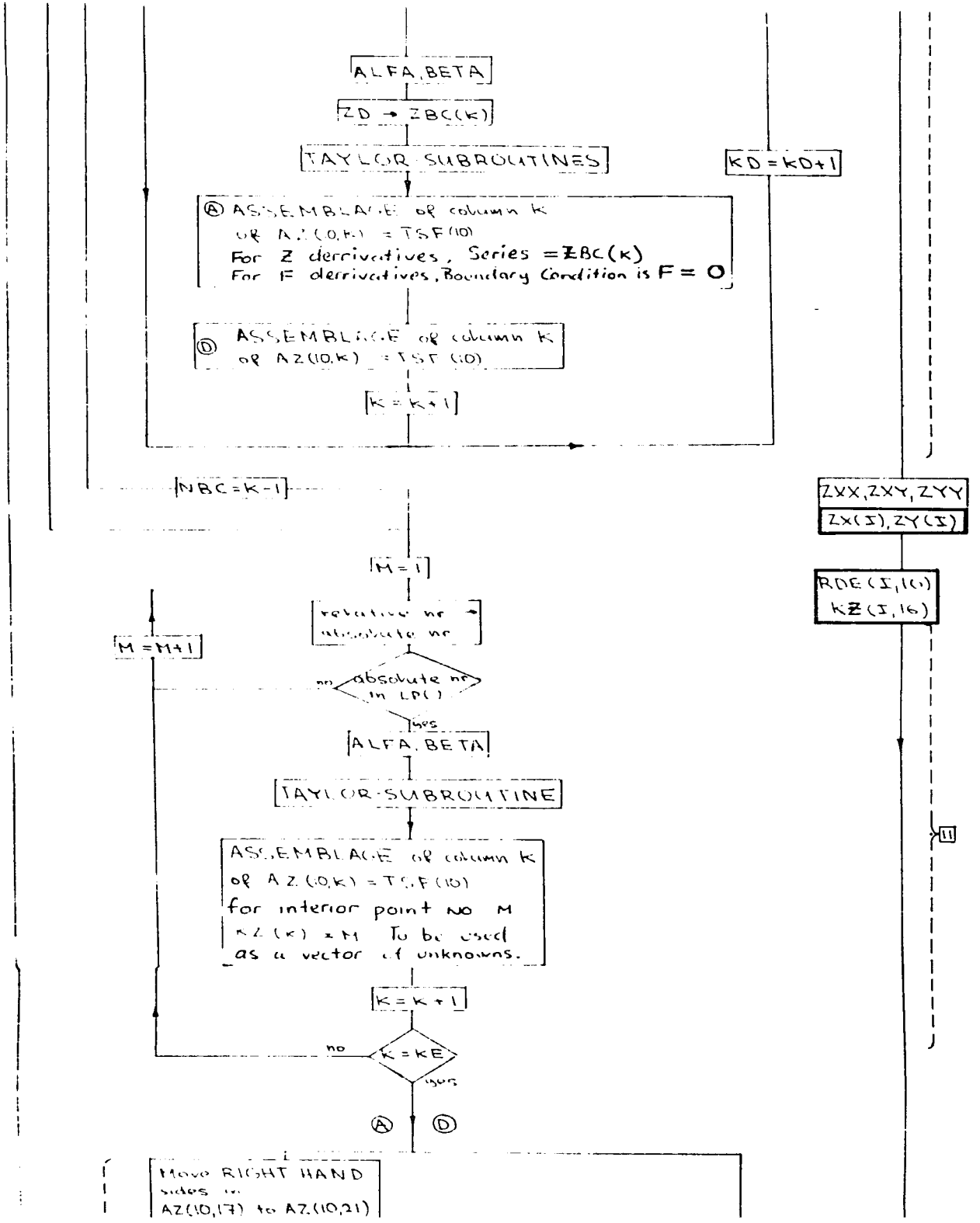
Flow Chart 1	Part 1	Input and Sorting of Data
Flow Chart 2	Part 2	Assemblage of Difference Equations
	Part 3	Solution of Difference Equations
	Part 4	Back Substitution
Flow Chart 3	Part 5	Boundary Points
Flow Chart 4	Part 6	Stress Resultants and Output

Flowchart 1 PART ONE

INPUT SORTING PRELIMINARY CALCULATIONS



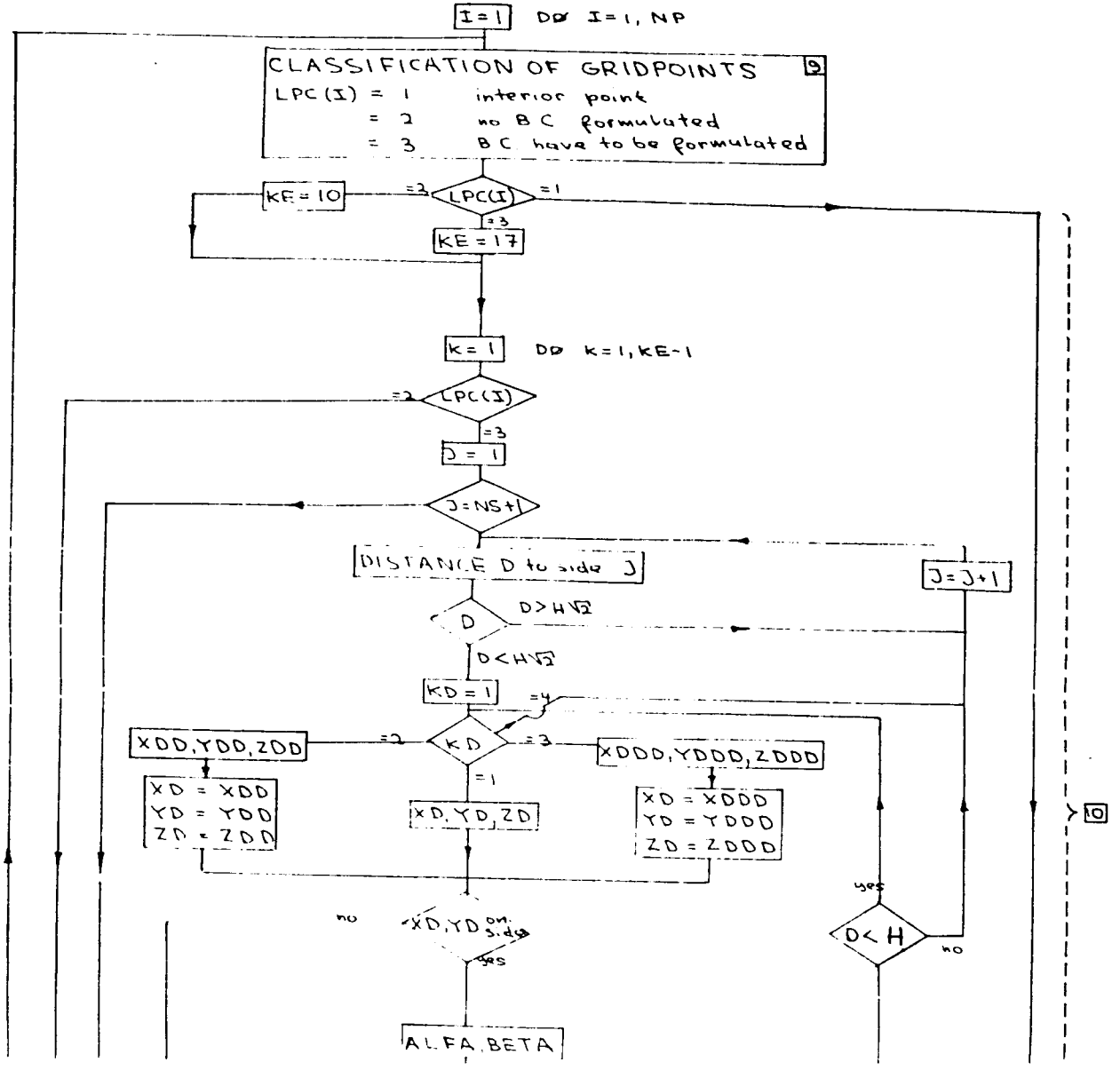

K = K + 1
no
K = KE
yes
A
D
Move RIGHT HAND sides in
AZ(10,17) to AZ(10,21)
First three R.H.S are used also for
SUBROUTINE JUDY
on AZ(10,21)
Find and write on tape
RFXX (I,10)
RFXY (I,10)
RFYY (I,10)
all depend on KZ(I,16)
Assemble Z(10)
→ ZXX ZXY ZYY
ZX(I) ZY(I)
RDE(I,10) = ZYY AF(10,17)
- 2 ZXY AF(10,18)
+ ZXX AF(10,19)
12
Move RIGHT HAND sides in
AZ(10,17) =
and
AZ(10,18) =
AZ(10,19) =
SUBROUTINE JUDY
on AZ(10,19)
→ RDE(I,10)
RZX(I,10)
RZY(I,10)
all depend on KZ(I,16)
modi. by Q(I)
13
I = I + 1
no
I = NP
yes
CALL PART 3 Solve

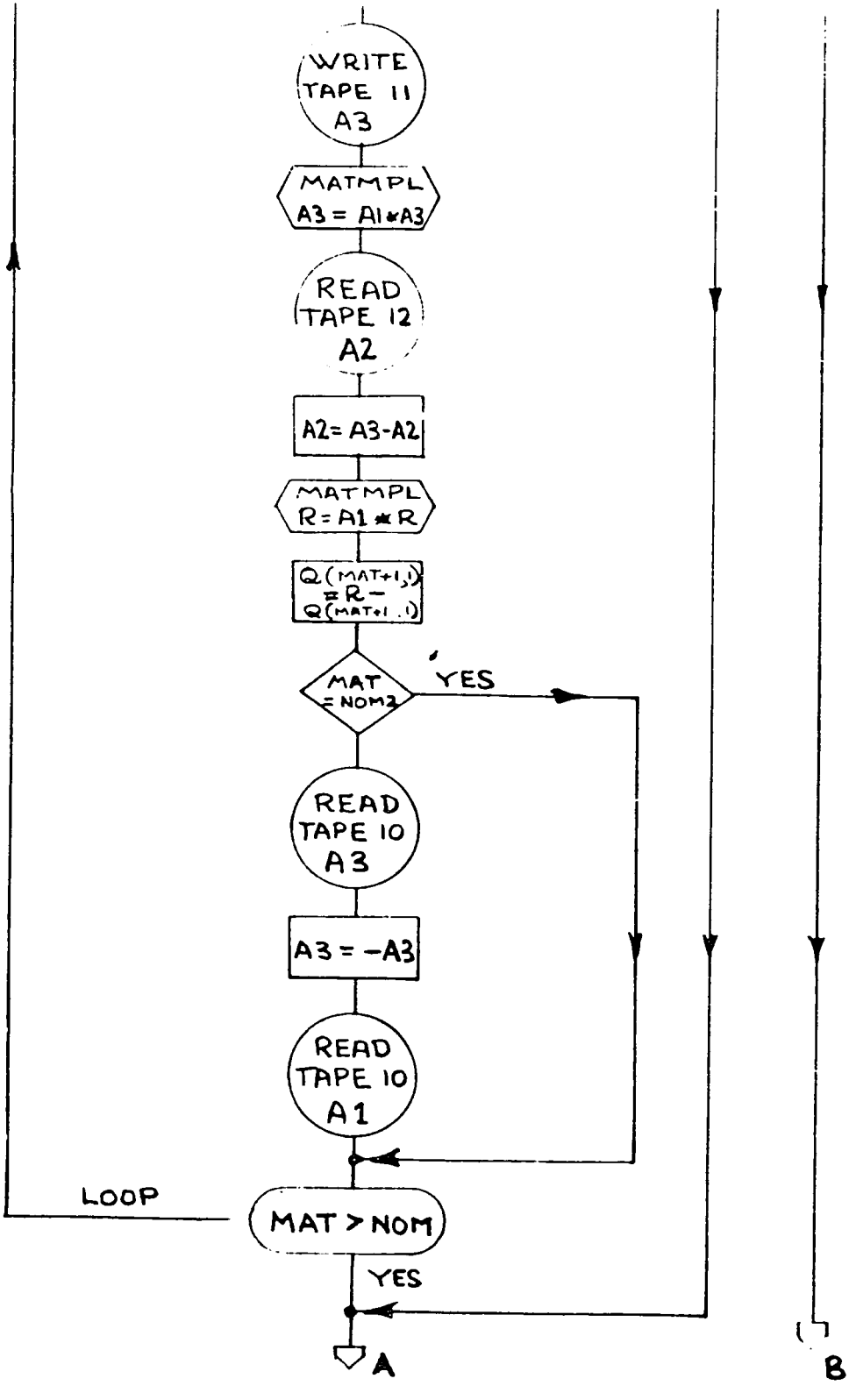

ALFA, BETA
ZD → ZBC(K)
TAYLOR SUBROUTINES
KD = KD+1
Ⓐ ASSEMBLAGE of column K
of AZ(10,K) = TSF(10)
For Z derivatives, Series = ZBC(K)
For F derivatives, Boundary Condition is F = 0
Ⓓ ASSEMBLAGE of column K
of AZ(10,K) = TSF(10)
K = K+1
NBC = K-1
ZXX, ZXY, ZYY
ZX(I), ZY(I)
M = 1
RDE(I,16)
KZ(I,16)
relative no → absolute no
M = M+1
absolute no in LP( )
no
yes
ALFA, BETA
TAYLOR SUBROUTINE
11
ASSEMBLAGE of column K
of AZ(10,K) = TSF(10)
for interior point NO M
KZ(K) = M To be used
as a vector of unknowns.
K = K+1
no
K = KE
yes
Ⓐ
Ⓓ
Move RIGHT HAND
sides to
AZ(10,17) to AZ(10,21)

156a

Flowchart 2 PART TWO

AUTOMATIC ASSEMBLAGE OF DIFFERENCE EQUATIONS IN GRIDPOINTS





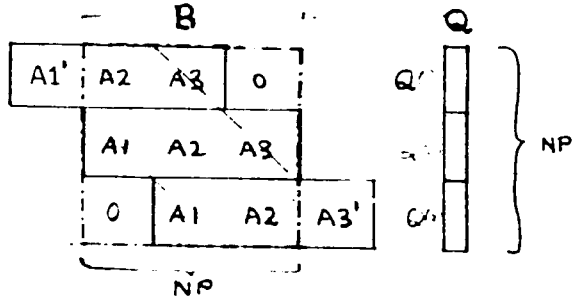


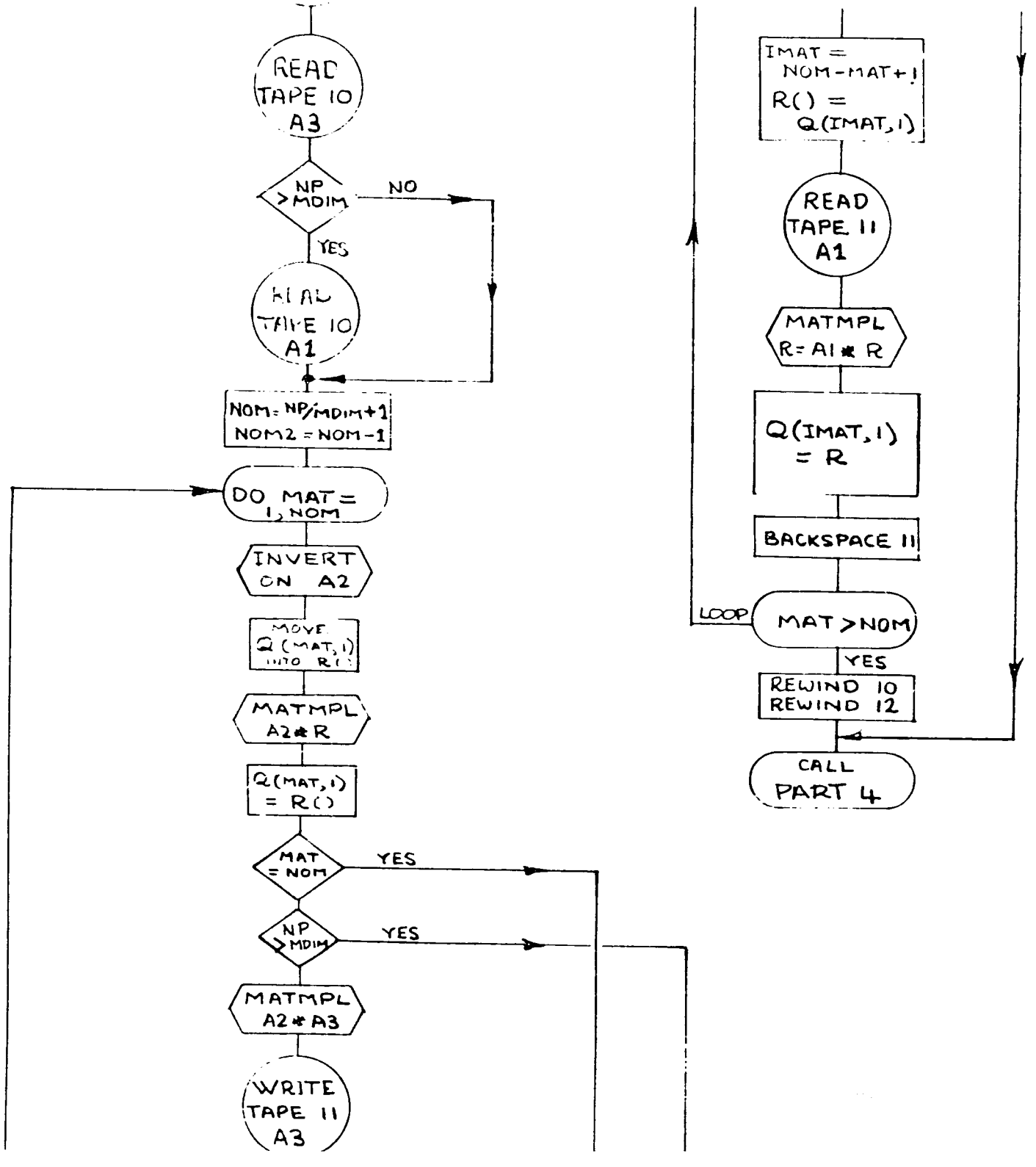
Diagram of partitioning.

Each Submatrix A1, A2, A3 is of size MDIM * MDIM. The shaded area only contains non-zero terms.

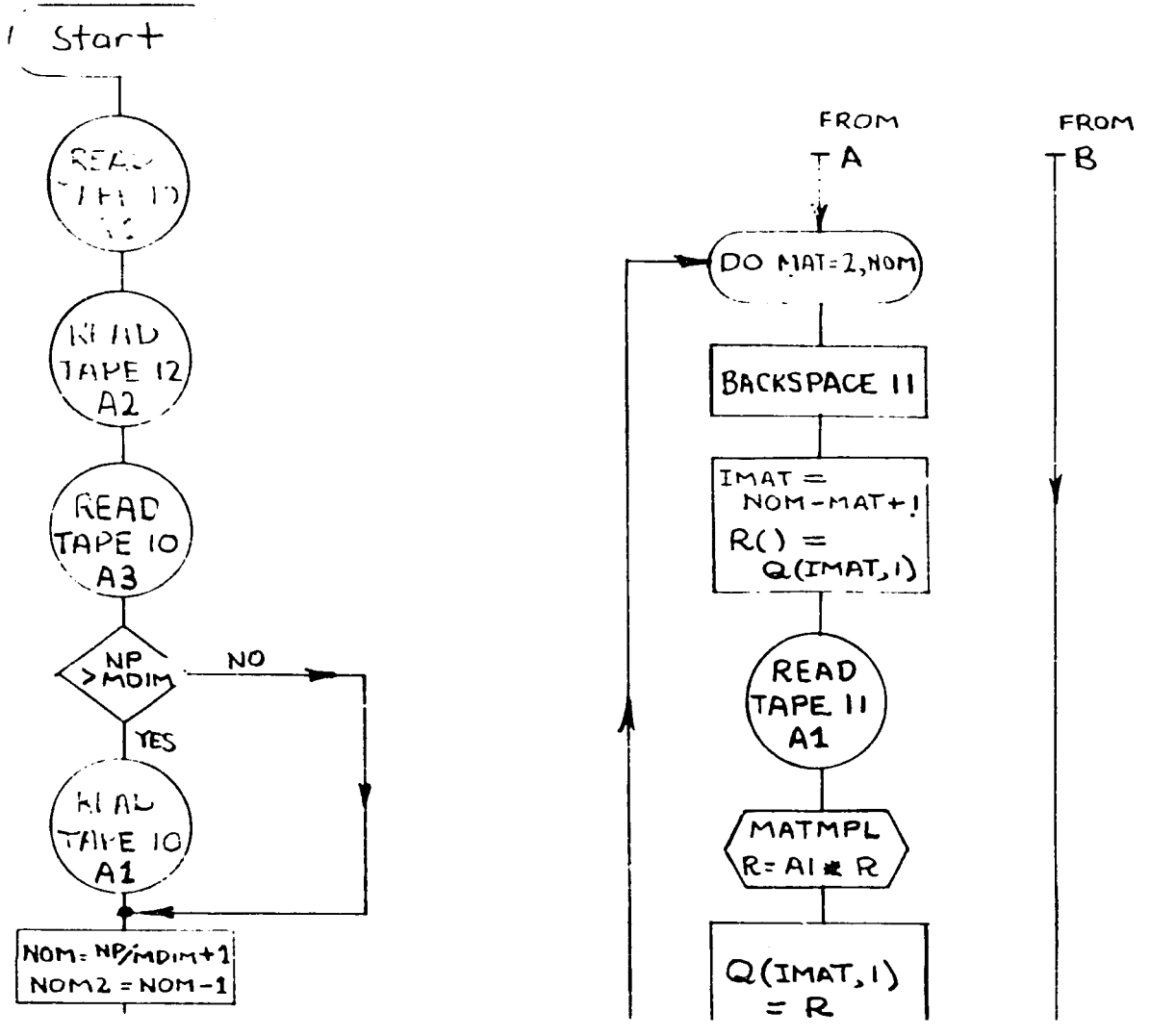
Note matrices A1' & A3' = 0.0 but are written on tape for convenience.

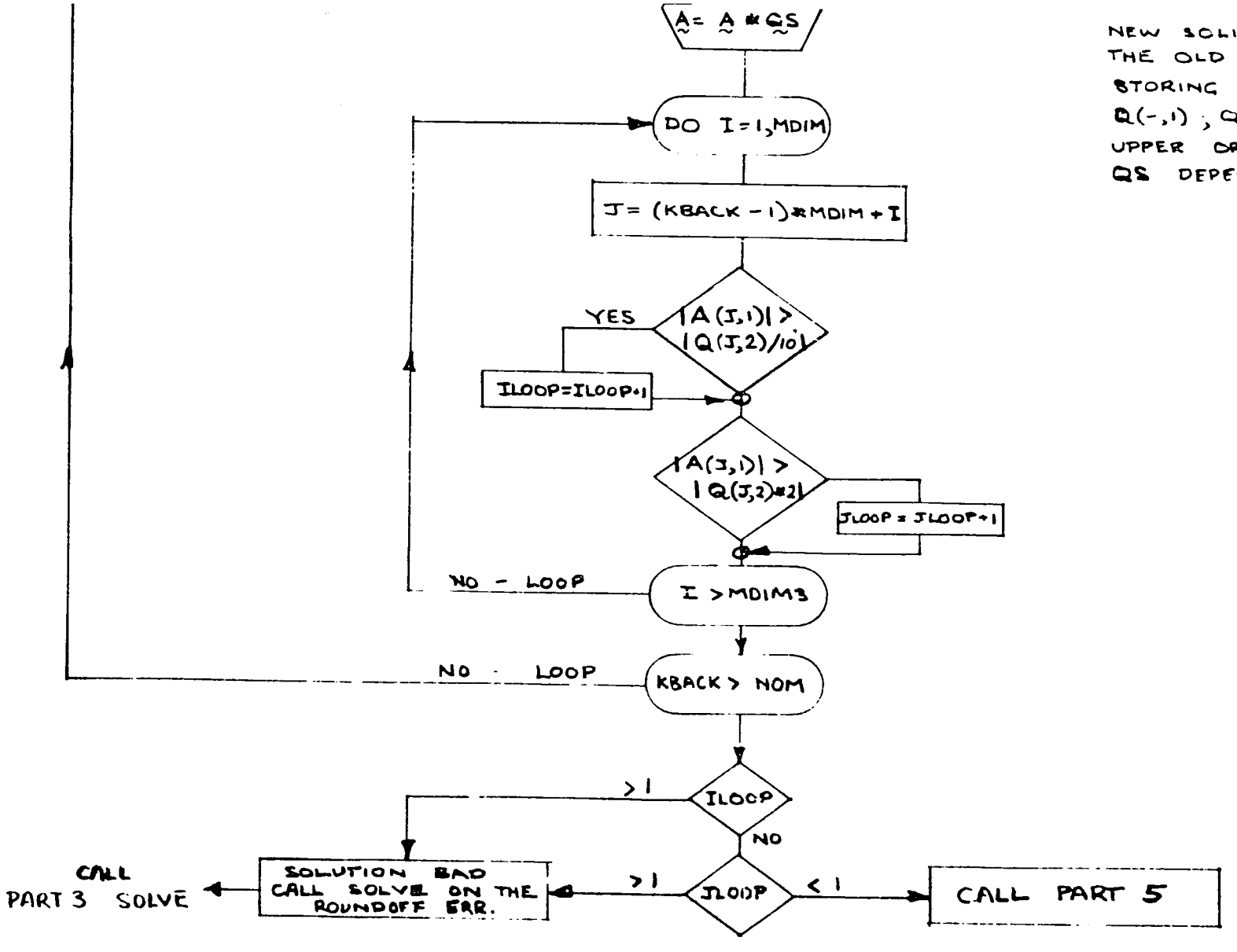
Subroutines:

Invert – Finds Inverse of Matrix
MATMPL – Multiplys two matrices

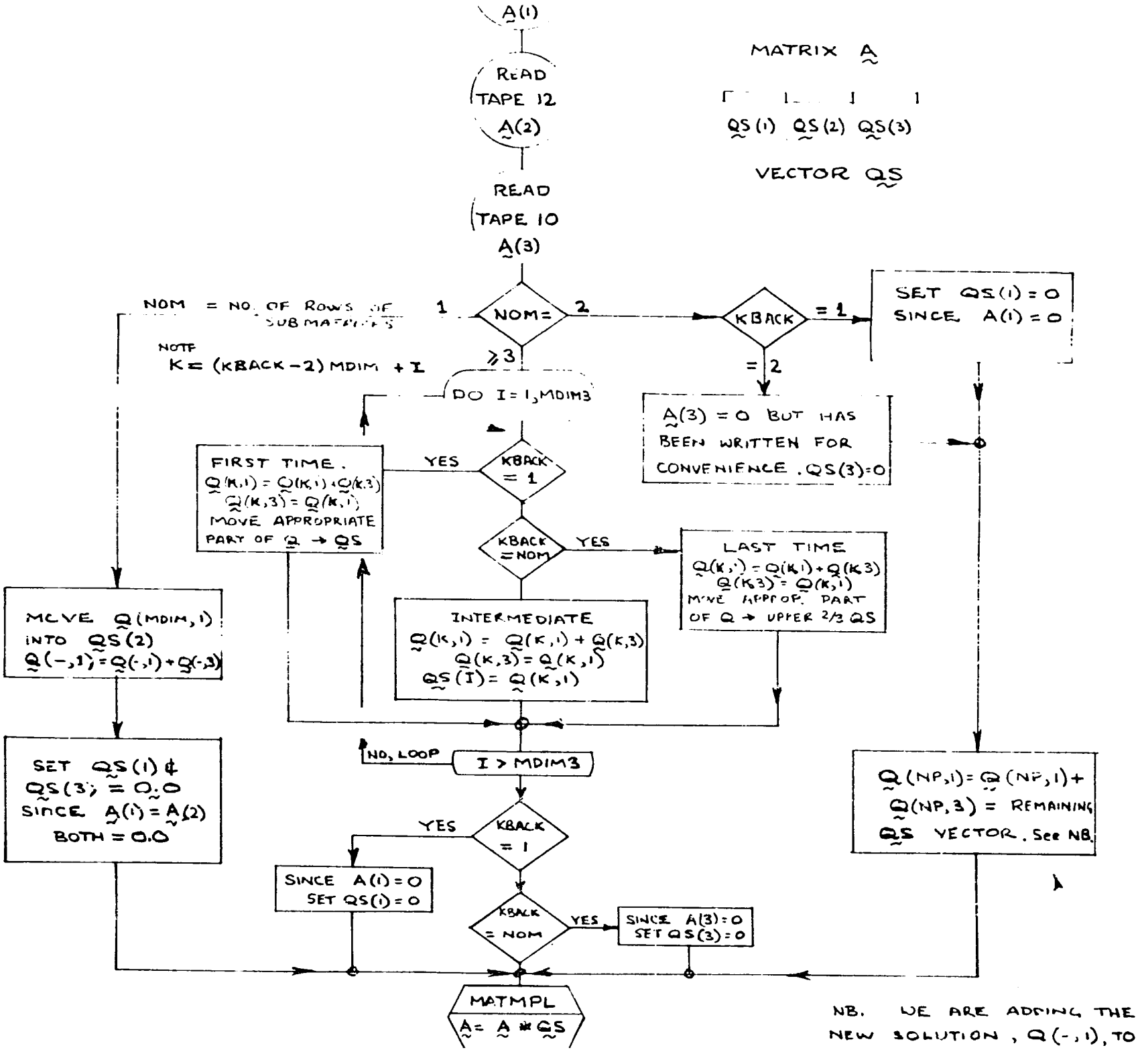

READ TAPE 10 A3
NP > MDIM
NO
YES
READ TAPE 10 A1
NOM = NP/MDIM+1
NOM2 = NOM-1
DO MAT = 1, NOM
INVERT ON A2
MOVE Q(MAT,1) INTO R()
MATMPL A2 * R
Q(MAT,1) = R()
MAT = NOM
YES
NP > MDIM
YES
MATMPL A2 * A3
WRITE TAPE 11 A3
IMAT = NOM-MAT+1
R() = Q(IMAT,1)
READ TAPE 11 A1
MATMPL R = A1 * R
Q(IMAT,1) = R
BACKSPACE 11
LOOP
MAT > NOM
YES
REWIND 10
REWIND 12
CALL PART 4

PART 3 SOLVER Calls "Invert" and "Matmpl".



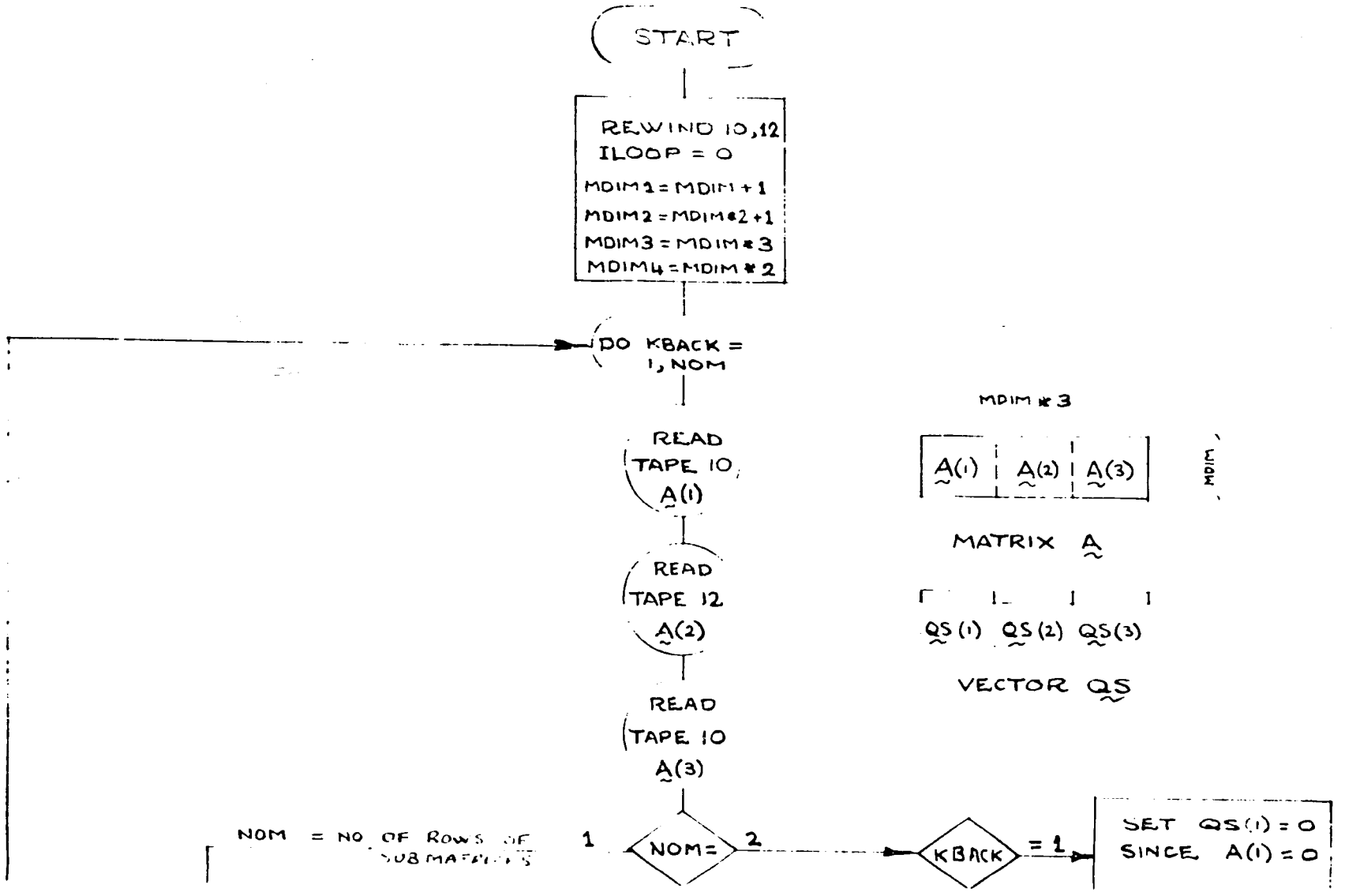


NEW SOLUTION, Q(-,1), TO THE OLD SOL. Q(-,3) AND STORING THE RESULT IN Q(-,1); Q(-,3) AND IN THE UPPER OR LOWER 2/3 OF QS DEPENDING ON KBACK.



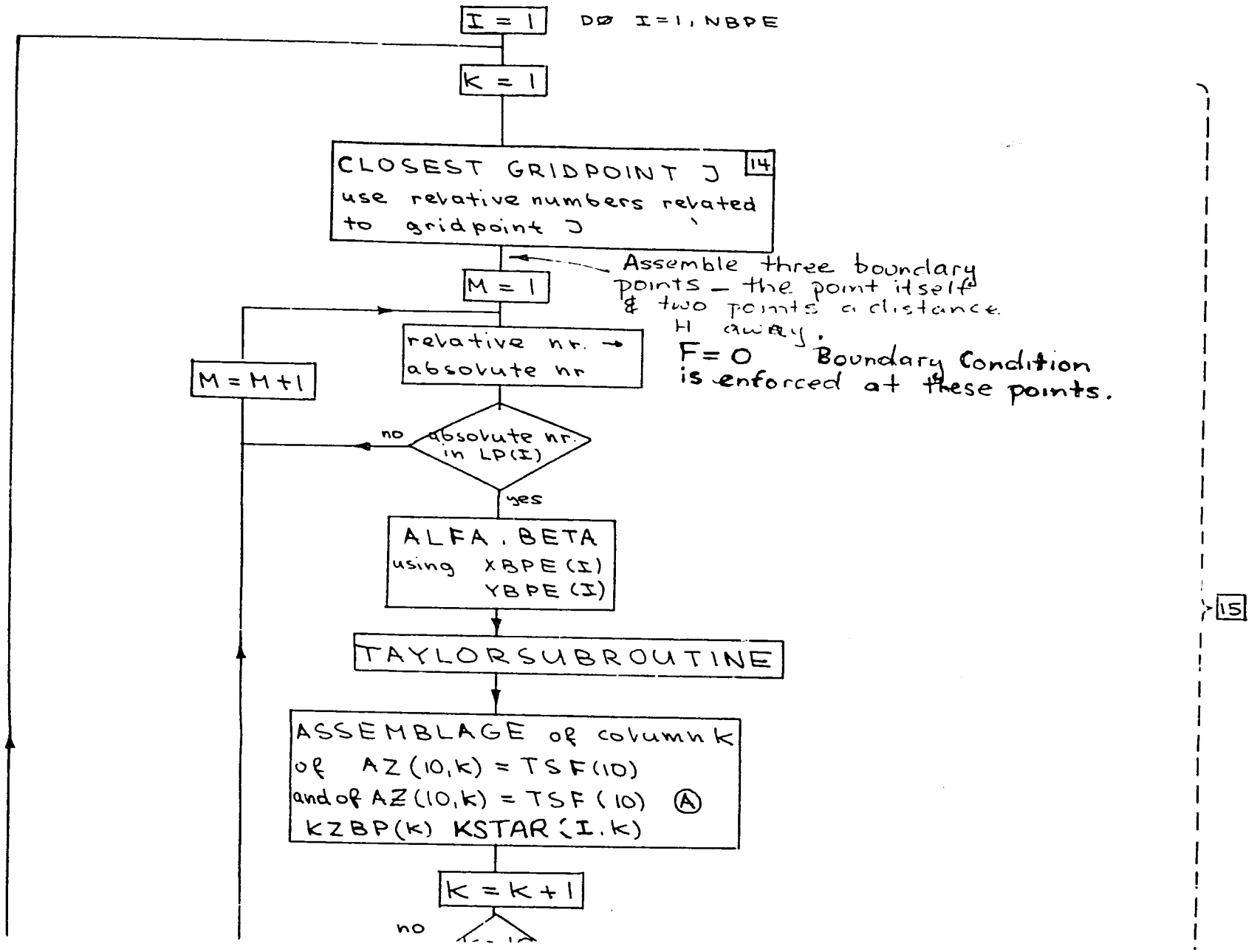
NB. WE ARE ADDING THE NEW SOLUTION, Q(-,1), TO

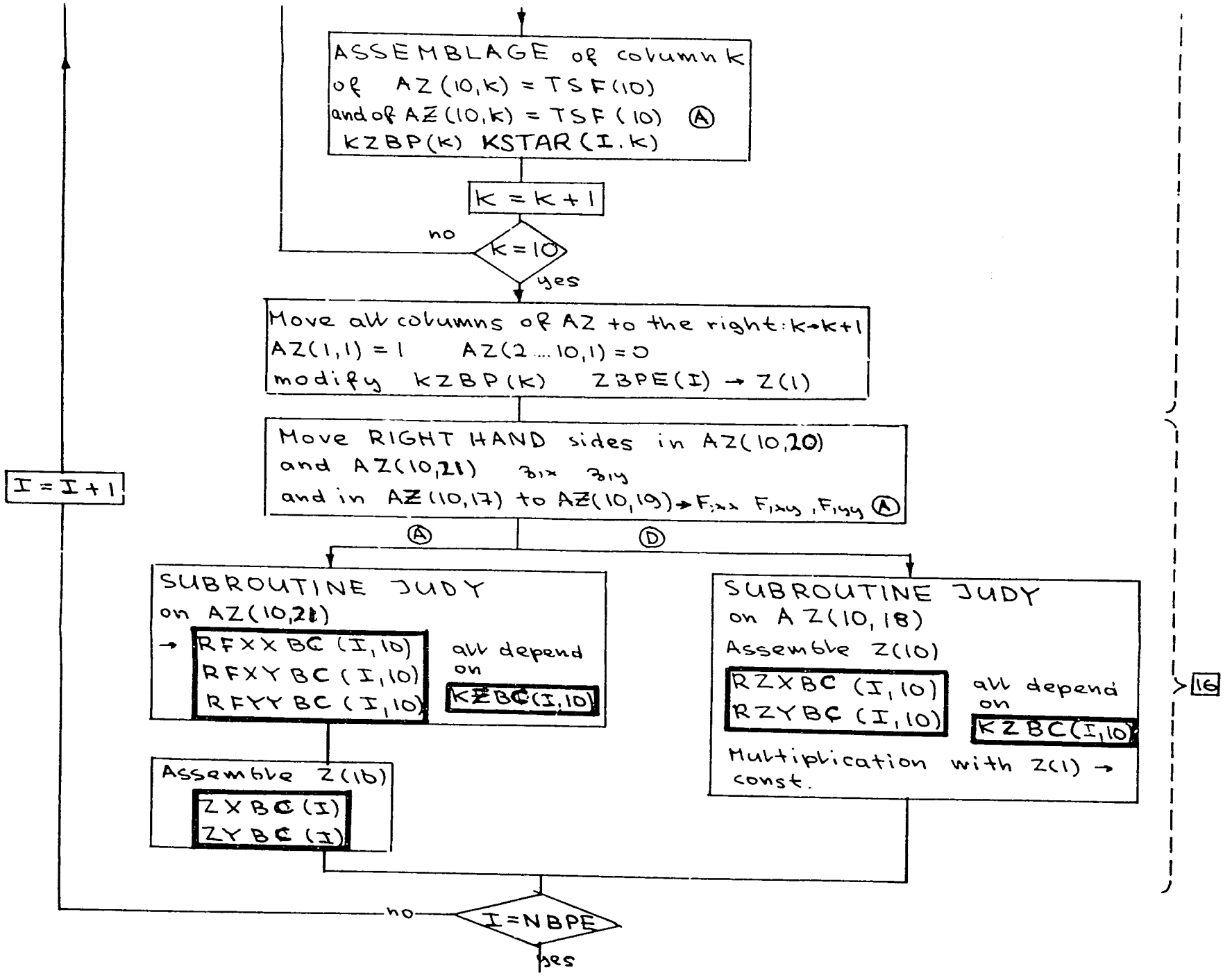
PART 5 BACKSUBSTITUTION IN BAND MATRI



Flowchart 3 PART FIVE

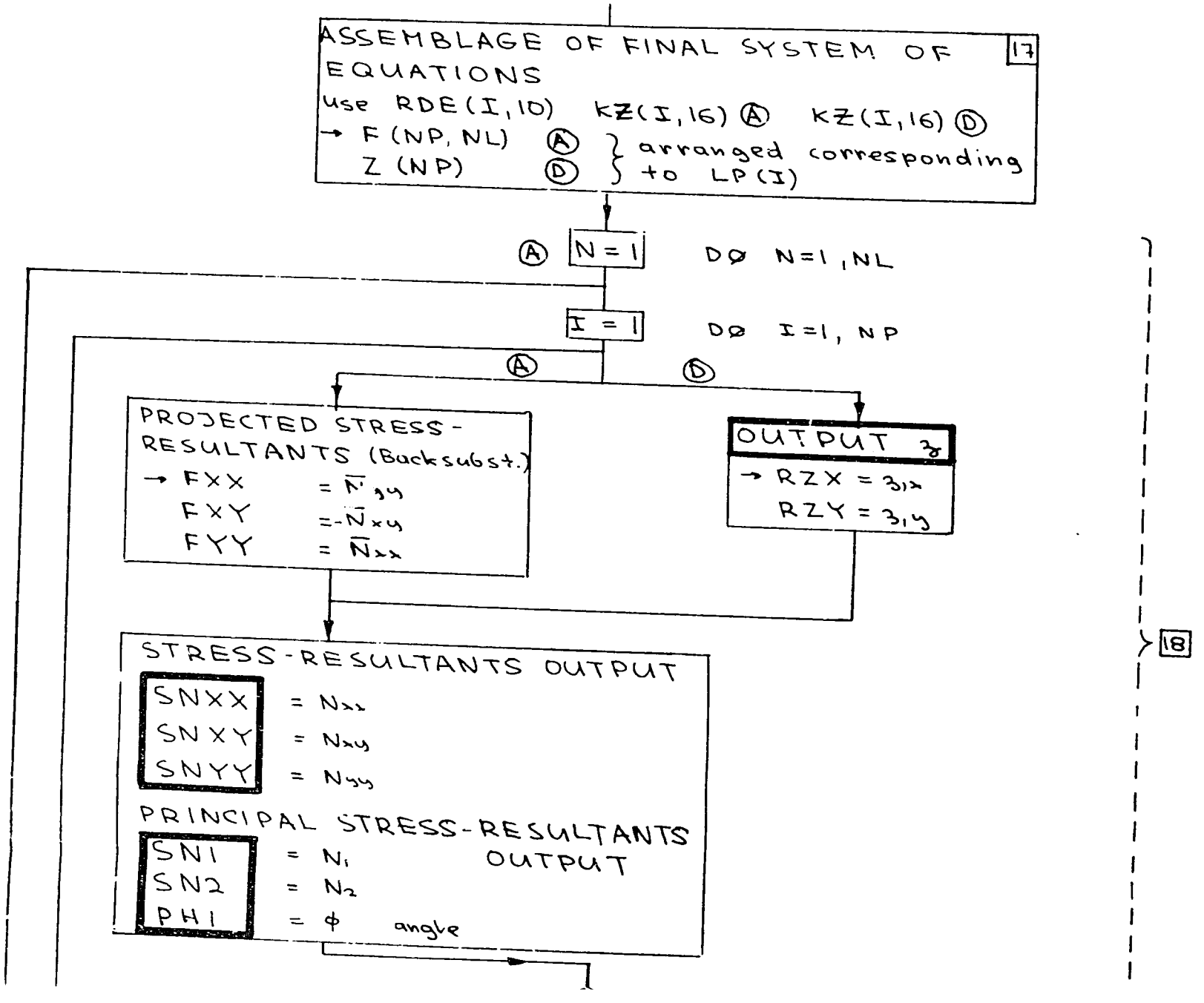
AUTOMATIC ASSEMBLAGE OF DIFFERENCE EQUATIONS IN POINTS ON THE BOUNDARY

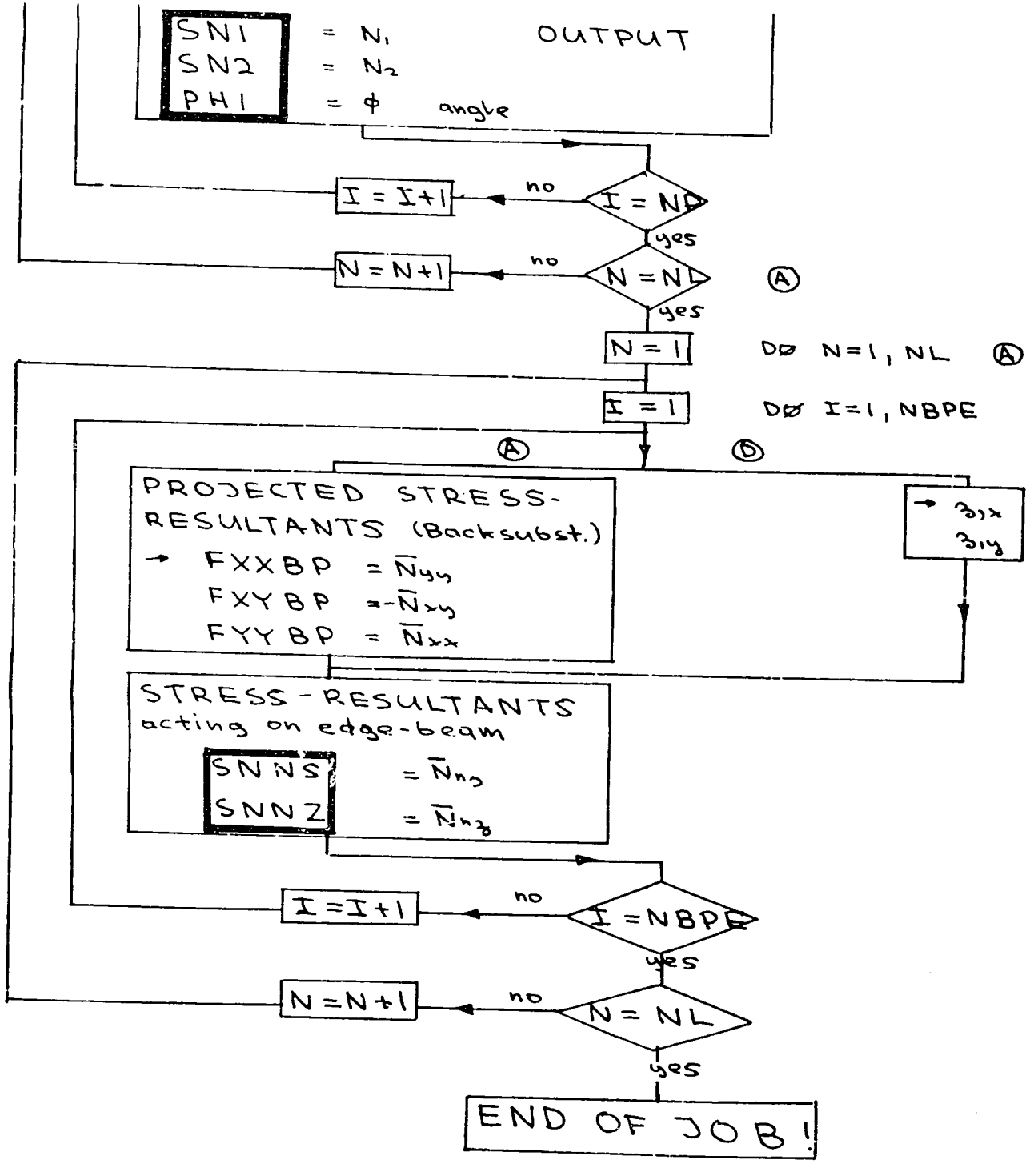



ASSEMBLAGE of column k
of AZ(10,k) = TSF(10)
and of AZ(10,k) = TSF(10) A
KZBP(k) KSTAR(I.k)
k = k + 1
no
k = 10
yes
Move all columns of AZ to the right: k→k+1
AZ(1,1) = 1 AZ(2 .... 10,1) = 0
modify KZBP(k) ZBPE(I) → Z(1)
Move RIGHT HAND sides in AZ(10,20)
and AZ(10,21) z_{1x} z_{1y}
and in AZ(10,17) to AZ(10,19) → F_{1xx} F_{1xy}, F_{1yy} A
A
D
SUBROUTINE JUDY
on AZ(10,21)
→ RFXXBC (I,10)
RFXYBC (I,10)
RFYYBC (I,10)
all depend on
KZBC(I,10)
Assemble Z(10)
ZXBC (I)
ZYBC (I)
SUBROUTINE JUDY
on AZ(10,18)
Assemble Z(10)
RZXBC (I,10)
RZYBC (I,10)
all depend on
KZBC(I,10)
Multiplication with Z(1) → const.
16
I = I + 1
no
I = NBPE
yes

Flowchart 4 PART SIX

SOLUTION BACKSUBSTITUTION OUTPUT




SN1 = N1
SN2 = N2
PH1 = φ angle
OUTPUT
I = I+1
no
I = ND
yes
N = N+1
no
N = NL
yes
A
N = 1
DØ N=1, NL
A
I = 1
DØ I=1, NBPE
A
D
PROJECTED STRESS-RESULTANTS (Backsubst.)
FXXBP = N̄yy
FXYBP = -N̄xy
FYYBP = N̄xx
→ 3,x
3,y
STRESS-RESULTANTS acting on edge-beam
SNNS = N̄ns
SNNZ = N̄nz
I = I+1
no
I = NBPE
yes
N = N+1
no
N = NL
yes
END OF JOB!

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APPENDIX E -- LISTING OF PROGRAM

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```
*       CHAIN (5,B1)
C     THIS LINK MERELY SETS THE POINTERS IPRINT AND INEXT.
        DIMENSION COE(10),TITLE(12),MCONS(3,100),MC(100),CPC(100,3),        JPW1000
       1LBP(500),LBPS(500),XBP(500),YBP(500),ZBP(500),COSS(100),SINS(100),  JPW1001
       2LP(561),LPC(561),Z(561),Q(561,3)                                    JPW1002
        COMMON COE,TITLE,MCONS,MC,CPC,LBP,LBPS,XBP,YBP,ZBP,COSS,SINS,LP,LP  JPW1003
       1C,Z,Q,INTSW,IEXQ,INEXT,NS,NC,NP,NL  ,IMID,MDIM,H,COE1,XORIG,YORIG   JPW1004
        COMMON AN,LX,IPRINT                                                 JPW1005
        IPRINT=0                                                            JPW1006
        INEXT=1                                                             JPW1008
        CALL CHAIN(1,B1)                                                    JPW1009
        END                                                                 JPW1010
```

```
*     CHAIN (1,B1)
*     LIST8                                                             JPW1011
*     LABEL                                                             JPW1012
CPART1                                                                  JPW1013
C   PHASE 1  READ AND CHECK DATA
      DIMENSION COE(10),TITLE(12),MCONS(3,100),MC(100),CPC(100,3),      JPW1014
     1LBP(500),LBPS(500),XBP(500),YBP(500),ZBP(500),COSS(100),SINS(100), JPW1015
     2LP(561),LPC(561),Z(561),Q(561,3)                                  JPW1016
      COMMON COE,TITLE,MCONS,MC,CPC,LBP,LBPS,XBP,YBP,ZBP,COSS,SINS,LP,LP JPW1017
     1C,Z,Q,INTSW,IEXQ,INEXT,NS,NC,NP,NL ,IMID,MDIM,H,COE1,XORIG,YORIG  JPW1018
      COMMON AN,LX,IPRINT                                               JPW1019
      DIMENSION QTEMP(3),AREA(33),NSC(33)                               JPW1020
F     DIRECT,DIREC2,LIST                                                JPW1021
  800 GO TO (901,1001),INEXT                                            JPW1022
  901 I=MATCH(LIST,K,1)                                                 JPW1023
      IF(I-5) 901,902,901                                               JPW1024
  902 IF(K-6)1001,1001,901                                              JPW1025
 1001 IEXQ=0                                                            JPW1026
C   IEXQ IS A POINTER FOR DELETION OF EXECUTION PHASE
      INEXT=1                                                           JPW1027
      IERR=0                                                            JPW1028
      READ 35,TITLE                                                     JPW1029
C   THE FIRST CARD IN THE DATA MUST BE A TITLE CARD
      PRINT 36                                                          JPW1031
      PRINT 37,TITLE                                                    JPW1032
  900 I=MATCH(DIRECT,IDIR,1)                                            JPW1033
C   THE SECOND CARD IN THE DATA MUST TELL WHAT TYPE OF PROBLEM IS TO BE SOLVED
      IF(I-5) 935,910,935                                               JPW1034
  910 IF(IDIR-6) 920,920,925                                            JPW1035
  920 INTSW=3                                                           JPW1036
      GO TO 1002                                                        JPW1037
  925 IERR=0                                                            JPW1038
  930 I=MATCH(DIREC2,IDIR,0)                                            JPW1039
      IF(I-5) 940,950,940                                               JPW1040
  940 IERR=IERR+1                                                       JPW1041
      IF(IERR-12) 930,935,935                                           JPW1042
  950 IF(IDIR-6) 960,960,970                                            JPW1043
  960 INTSW=2                                                           JPW1044
      GO TO 1002                                                        JPW1045
  970 INTSW=1                                                           JPW1046
      GO TO 1002                                                        JPW1047
  935 PRINT 936                                                         JPW1048
```

```
      INTSW=1                                                           JPW1049
 1002 READ 1,NS,NC                                                      JPW1050
C   NS=NUMBER OF SIDES    NC=NUMBER OF CONTOURS
      PRINT 982                                                         JPW1051
      GO TO (980,972,962),INTSW                                         JPW1052
  962 PRINT 961                                                         JPW1053
      GO TO 1003                                                        JPW1054
  972 PRINT 971                                                         JPW1055
      GO TO 1003                                                        JPW1056
  980 PRINT 981                                                         JPW1057
 1003 PRINT 1004,NS,NC                                                  JPW1058
      DO 1000 J=1,NS                                                    JPW1059
 1000 READ 2,MCONS(1,J),MCONS(2,J),MCONS(3,J)                           JPW1060
C   MCONS IS CONNECTIVITY MATRIX FOR ALL CONTOURS
      PRINT 56                                                          JPW1061
      IF(NS-15) 1005,1005,1006                                          JPW1062
 1005 PRINT 1009,(MCONS(1,I),I=1,NS)                                    JPW1063
      PRINT 1007,(MCONS(2,I),I=1,NS)                                    JPW1064
      PRINT 1008,(MCONS(3,I),I=1,NS)                                    JPW1065
      PRINT 21                                                          JPW1066
      GO TO 1011                                                        JPW1067
 1006 PRINT 1012                                                        JPW1068
      DO 1013 I=1,NS                                                    JPW1069
 1013 PRINT 1014,(MCONS(J,I),J=1,3)                                     JPW1070
      PRINT 21                                                          JPW1071
 1011 NCCHEC=0                                                          JPW1072
      NSIDEC=1                                                          JPW1073
C   THE SIDES ARE NOW ORDERED INTO CONTOURS IN THE CONNECTIVITY MATRIX
      DO 1010 JSORT=1,NS                                                JPW1074
      IF(JSORT-NS) 1020,1031,1020                                       JPW1075
 1020 ISERCH=JSORT+1                                                    JPW1076
      DO 1030 ISORT=ISERCH,NS                                           JPW1077
      IF(MCONS(3,JSORT)-MCONS(2,ISORT)) 1035,1040,1035                  JPW1078
 1035 IF(MCONS(3,JSORT)-MCONS(3,ISORT)) 1030,1036,1030                  JPW1079
 1030 CONTINUE                                                          JPW1080
 1031 NCCHEC=NCCHEC+1                                                   JPW1081
      NSC(NCCHEC)=NSIDEC                                                JPW1082
      IF(NSIDEC-2) 1900,1900,1050                                       JPW1083
C   ADDRESS 1900 IS AN ERROR CODE (INSUFFICIENT SIDES IN A CONTOUR)
 1050 NSIDEC=1                                                          JPW1084
      GO TO 1010                                                        JPW1085
 1036 ITEMP=MCONS(2,ISORT)                                              JPW1086
```

```
      MCONS(2,ISORT)=MCONS(3,ISORT)                                     JPW1087
      MCONS(3,ISORT)=ITEMP                                              JPW1088
 1040 DO 1060 ISWICH=1,3                                                JPW1089
      ITEMP=MCONS(ISWICH,ISERCH)                                        JPW1090
      MCONS(ISWICH,ISERCH)=MCONS(ISWICH,ISORT)                          JPW1091
 1060 MCONS(ISWICH,ISORT)=ITEMP                                         JPW1092
      NSIDEC=NSIDEC+1                                                   JPW1093
 1010 CONTINUE                                                          JPW1094
      IF(NCCHEC-NC) 1910,1070,1910                                      JPW1095
C   ADDRESS 1910 IS AN ERROR CODE-NUMBER OF CONTOURS DISAGREES WITH DATA
C   THE CONNECTIVITY MATRIX IS CHECKED FOR SIDE AND CORNER NUMBER WHICH ARE USED
C           MORE THAN ONCE
 1070 DO 1100 ITWICE=1,3                                                JPW1096
      DO 1101 JTWICE=1,NS                                               JPW1097
      DO 1102 KTWICE=1,NS                                               JPW1098
      IF(KTWICE-JTWICE) 1110,1102,1110                                  JPW1099
 1110 IF(MCONS(ITWICE,JTWICE)-MCONS(ITWICE,KTWICE)) 1102,1115,1102      JPW1100
 1115 IF(ITWICE-1) 1940,1930,1940                                       JPW1101
C   ADDRESS 1930 AND 1940 ARE ERROR CODES FOR SIDE AND CORNER POINT NUMBERS USED
C           MORE THAN ONCE
 1102 CONTINUE                                                          JPW1102
 1101 CONTINUE                                                          JPW1103
 1100 CONTINUE                                                          JPW1104
C   THE CONNECTIVITY MATRIX IS NOW CHECKED FOR DISCONTINUITIES  IN THE CONTOURS
C   ADDRESS 1950 IS AN ERROR CODE FOR SUCH DISCONTINUITIES
      LCLOSE=0                                                          JPW1105
      KCLOSE=1                                                          JPW1106
      DO 1120 JCLOSE=1,NC                                               JPW1107
      LCLOSE=NSC(JCLOSE)+LCLOSE                                         JPW1108
      IF(MCONS(3,LCLOSE)-MCONS(2,KCLOSE))1950,1120,1950                 JPW1109
 1120 KCLOSE=LCLOSE+1                                                   JPW1110
      DO 1130 ICPRED=1,NS                                               JPW1111
 1140 READ 4,MC(ICPRED),CPC(ICPRED,1),CPC(ICPRED,2),CPC(ICPRED,3)       JPW1112
C   MC=THE LIST OF CORNER POINT NUMBERS
C   CPC=THE CORNER POINT COORDINATES X,Y AND Z
      JMCHEK=0                                                          JPW1113
C   THE CONNECTIVITY MATRIX IS CHECKED TO SEE IF ALL CORNER POINTS MENTIONED
C   THERE, ARE ALSO MENTIONED IN MC=THE LIST OF CORNER POINTS MENTIONED
      DO 1150 IMCHEK=1,NS                                               JPW1114
      IF(MC(ICPRED)-MCONS(3,IMCHEK)) 1150,1160,1150                     JPW1115
 1160 JMCHEC=1                                                          JPW1116
 1150 CONTINUE                                                          JPW1117
```

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      IF(JMCHEC)1960,1960,1130                                          JPW1118
 1130 CONTINUE                                                          JPW1119
      PRINT 57,NS                                                       JPW1120
      PRINT 59                                                          JPW1121
      PRINT 58,(MC(I),(CPC(I,J),J=1,3),I=1,NS)                          JPW1122
C    THE CONNECTIVITY MATRIX IS NOW ORDERED SO THAT THE CONTOURS APPEAR IN
C    POSITIVE ORDER.   THE POSITIVE DIRECTION  IS SUCH THAT THE SHELL IS ALWAYS
C    ON THE LEFT AS ONE PROCEEDS ALONG THE BOUNDARY
      AMAX=0.0                                                          JPW1123
      JAREA2=0                                                          JPW1124
      DO 1170 IAREA=1,NC                                                JPW1125
      AREA(IAREA)=0.0                                                   JPW1126
      JAREA=NSC(IAREA)                                                  JPW1127
      DO 1185 KAREA=1,JAREA                                             JPW1128
      JAREA2=JAREA2+1                                                   JPW1129
      DO 1181 IFIND=1,NS                                                JPW1130
      IF(MC(IFIND)-MCONS(3,JAREA2))1182,1183,1182                       JPW1131
 1183 MAREA=IFIND                                                       JPW1132
 1182 IF(MC(IFIND)-MCONS(2,JAREA2))1181,1184,1181                       JPW1133
 1184 NAREA=IFIND                                                       JPW1134
 1181 CONTINUE                                                          JPW1135
 1185 AREA(IAREA)=AREA(IAREA)+(CPC(MAREA,1)-CPC(NAREA,1))*(CPC(MAREA,2)+ JPW1136
     1CPC(NAREA,2))/2.0                                                 JPW1137
      IF(ABSF(AREA(IAREA))-AMAX) 1170,1170,1190                         JPW1138
 1190 IMAX=IAREA                                                        JPW1139
      AMAX=ABSF(AREA(IAREA))                                            JPW1140
 1170 CONTINUE                                                          JPW1141
      IF(IMAX-1) 1180,1180,1195                                         JPW1142
 1195 ISUM=0                                                            JPW1143
      JSUM=NSC(IMAX)                                                    JPW1144
C    THE EXTERIOR BOUNDARY CONTOUR IS PLACED FIRST IN THE CONNECTIVITY MATRIX
C    THIS BOUNDARY IS DEFINED AS THE ONE WHICH CONTAINS THE LARGEST AREA
      DO 1200 I=1,IMAX                                                  JPW1145
 1200 ISUM=ISUM+NSC(I)                                                  JPW1146
      LSUM=ISUM-1                                                       JPW1147
      DO 1210 I=1,3                                                     JPW1148
      DO 1220 J=1,JSUM                                                  JPW1149
      ITEMP=MCONS(I,ISUM)                                               JPW1150
      DO 1230 K=1,LSUM                                                  JPW1151
      KSUM=ISUM-K                                                       JPW1152
 1230 MCONS(I,KSUM+1)=MCONS(I,KSUM)                                     JPW1153
 1220 MCONS(I,1)=ITEMP                                                  JPW1154
```

```
 1210 CONTINUE                                                          JPW1155
      ISUM=IMAX-1                                                       JPW1156
      DO 1250 I=1,ISUM                                                  JPW1157
      LSUM=IMAX-I                                                       JPW1158
 1250 NSC(LSUM+1)=NSC(LSUM)                                             JPW1159
      NSC(1)=JSUM                                                       JPW1160
 1180 DO 1260 IFINAL=1,NC                                               JPW1161
      IF(IFINAL-1) 1270,1280,1270                                       JPW1162
 1280 IF(AREA(1)) 1260,1260,1290                                        JPW1163
 1270 IF(AREA(IFINAL)) 1290,1290,1260                                   JPW1164
 1290 JFINAL=NSC(IFINAL)                                                JPW1165
      IFTOT=0                                                           JPW1166
      DO 1300 KFINAL=1,IFINAL                                           JPW1167
 1300 IFTOT=IFTOT+NSC(KFINAL)                                           JPW1168
      MFINAL=IFTOT-NSC(IFINAL)+1                                        JPW1169
      JBEEP=MFINAL                                                      JPW1170
      KBEEP=IFTOT                                                       JPW1171
 1310 ITEMP=MCONS(1,JBEEP)                                              JPW1172
      MCONS(1,JBEEP)=MCONS(1,KBEEP)                                     JPW1173
      MCONS(1,KBEEP)=ITEMP                                              JPW1174
      JBEEP=JBEEP+1                                                     JPW1175
      KBEEP=KBEEP-1                                                     JPW1176
      IF(KBEEP-JBEEP) 1320,1320,1310                                    JPW1177
 1320 KBEEP=IFTOT                                                       JPW1178
      DO 1330 I=MFINAL,IFTOT                                            JPW1179
      ITEMP=MCONS(3,KBEEP)                                              JPW1180
      MCONS(3,KBEEP)=MCONS(2,I)                                         JPW1181
      MCONS(2,I)=ITEMP                                                  JPW1182
 1330 KBEEP=KBEEP-1                                                     JPW1183
 1260 CONTINUE                                                          JPW1184
C   THE COSINES AND SINES OF THE ANGLE BETWEEN THE PROJECTED SIDES AND THE X
C           AXES ARE CALCULATED
      DO 1350 IANGLE=1,NS                                               JPW1185
      DO 1351 I=1,NS                                                    JPW1186
      IF(MC(I)-MCONS(3,IANGLE)) 1352,1353,1352                          JPW1187
 1352 IF(MC(I)-MCONS(2,IANGLE)) 1351,1354,1351                          JPW1188
 1353 JANGLE=I                                                          JPW1189
      GO TO 1351                                                        JPW1190
 1354 KANGLE=I                                                          JPW1191
 1351 CONTINUE                                                          JPW1192
      COSS(IANGLE)=(CPC(JANGLE,1)-CPC(KANGLE,1))/(SQRTF((CPC(JANGLE,1)-C JPW1193
     1PC(KANGLE,1))**2+(CPC(JANGLE,2)-CPC(KANGLE,2))**2))               JPW1194
```

```
 1350 SINS(IANGLE)=(CPC(JANGLE,2)-CPC(KANGLE,2))/(SQRTF((CPC(JANGLE,1)-  JPW1195
     1CPC(KANGLE,1))**2+(CPC(JANGLE,2)-CPC(KANGLE,2))**2))              JPW1196
      READ 5,NP,NL                                                      JPW1197
C    THE NUMBER OF INTERIOR POINTS (NP) AND THE NUMBER OF LOADING CONDITIONS (NL)
C    ARE READ INTO THE PROGRAM
      READ 8,H                                                          JPW1198
C    THE GRID SIZE (H) IS READ
      PRINT 60                                                          JPW1199
      PRINT 41,NP,NL                                                    JPW1200
      PRINT 42,H                                                        JPW1201
      IF(NP-500)  2004,2004,2005                                        JPW1202
 2004 IF(NL-1) 2006,2006,2007                                           JPW1203
 2006 DO 1360 LSTRED=1,NP                                               JPW1204
 1360 READ 6,LP(LSTRED),Z(LSTRED),(Q(LSTRED,MSTRED),MSTRED=1,NL)        JPW1205
C    THE LIST OF POINTS  LP,THE Z COORDINATES OF EACH POINT,  AND THE PROJECTED
C    VERTICAL LOAD Q FOR EACH LOADING CONDITION ARE READ
      GO TO (1355,1356,1357),INTSW                                      JPW1206
 1357 READ 8,AN                                                         JPW1207
      PRINT 2013,AN                                                     JPW1208
      GO TO 1355                                                        JPW1209
 1356 READ 38,(COE(I),I=1,10)                                           JPW1210
      READ 8,COE1                                                       JPW1211
      READ 40,XORIG,YORIG                                               JPW1212
 1355 ITEMP=NP-1                                                        JPW1213
      GO TO (1371,1372,1371),INTSW                                      JPW1214
 1372 DO 1373 I=1,NP                                                    JPW1215
      IY=LP(I)/100                                                      JPW1216
      IX=LP(I)-IY*100                                                   JPW1217
      X=IX                                                              JPW1218
      Y=IY                                                              JPW1219
      X=X*H                                                             JPW1220
      Y=Y*H                                                             JPW1221
      Y=Y-YORIG                                                         JPW1222
      X=X-XORIG                                                         JPW1223
      IF(ABSF(COE1-.5)-.001) 1376,1376,1374                             JPW1224
 1376 Z(I)=SQRTF(COE(1)*Y**3+COE(2)*X*Y*Y+COE(3)*Y*X*X+COE(4)*X**3+COE(5 JPW1225
     1)*Y**2+COE(6)*X*Y+COE(7)*X**2+COE(8)*Y+COE(9)*X+COE(10))          JPW1226
      GO TO 1373                                                        JPW1227
 1374 Z(I)=     (COE(1)*Y**3+COE(2)*X*Y*Y+COE(3)*Y*X*X+COE(4)*X**3+COE(5) JPW1228
     1*Y**2+COE(6)*X*Y+COE(7)*X**2+COE(8)*Y+COE(9)*X+COE(10))           JPW1229
 1373 CONTINUE                                                          JPW1230
 1371 PRINT 43                                                          JPW1231
```

```
      DO 1776 I=1,NP                                                    JPW1232
 1776 PRINT 44, LP(I),Z(I),(Q(I,J),J=1,NL)                              JPW1233
      IF(INTSW-2) 1729,1377,1727                                        JPW1234
 1377 PRINT 45,(COE(I),I=1,10),COF1                                     JPW1235
      PRINT 46,XORIG,YORIG                                              JPW1236
      GO TO 1729                                                        JPW1237
 1727 DO 1728 I=1,NP                                                    JPW1238
 1728 Q(I,1)=Q(I,1)/AN                                                  JPW1239
C    THE LIST OF POINTS (LP) IS SORTED SO THAT THEY APPEAR IN RISING ORDER ALONG
C    THE SMALLER DIMENSION OF THE SHELL
 1729 MINLP1=9999                                                       JPW1240
      MINLP2=9999                                                       JPW1241
      MAXLP1=0000                                                       JPW1242
      MAXLP2=0000                                                       JPW1243
      IDIR3=1                                                           JPW1244
      DO 1730 I=1,NP                                                    JPW1245
      IF(MAXLP1-LP(I)) 1731,1732,1732                                   JPW1246
 1731 MAXLP1=LP(I)                                                      JPW1247
 1732 IF(MINLP1-LP(I)) 1733,1733,1734                                   JPW1248
 1734 MINLP1=LP(I)                                                      JPW1249
 1733 KTEMP=LP(I)/100                                                   JPW1250
      JTEMP=LP(I)-KTEMP*100                                             JPW1251
      LTEMP=JTEMP*100+KTEMP                                             JPW1252
      IF(MAXLP2-LTEMP) 1735,1736,1736                                   JPW1253
 1735 MAXLP2=LTEMP                                                      JPW1254
 1736 IF(MINLP2-LTEMP)1730,1730,1737                                    JPW1255
 1737 MINLP2=LTEMP                                                      JPW1256
 1730 CONTINUE                                                          JPW1257
      MIN3=MAXLP1-MINLP1                                                JPW1258
      MIN2=MAXLP2-MINLP2                                                JPW1259
      IF(MIN3-MIN2) 1738,1739,1739                                      JPW1260
 1739 IDIR3=2                                                           JPW1261
      MDIM=((MAXLP2/100-MINLP2/100)+1)*2+3                              JPW1262
      GO TO 1362                                                        JPW1263
 1738 MDIM=((MAXLP1/100-MINLP1/100)+1)*2+3                              JPW1264
      DO 1740 I=1,NP                                                    JPW1265
      KTEMP=LP(I)/100                                                   JPW1266
 1740 LP(I)=(LP(I)-KTEMP*100)*100+KTEMP                                 JPW1267
 1362 DO 1720 JSORT=1,NP                                                JPW1268
      DO 1720 I=1,ITEMP                                                 JPW1269
      IF(LP(I)-LP(I+1)) 1720,1720,1701                                  JPW1270
 1701 KTEMP=LP(I)                                                       JPW1271
```

```
      ZTEMP=Z(I)
      DO 1703 IFT=1,NL                                                  JPW1272
 1703 QTEMP(IFT)=Q(I,IFT)                                               JPW1273
      LP(I)=LP(I+1)                                                     JPW1274
      Z(I)=Z(I+1)                                                       JPW1275
      DO 1704 IFT=1,NL                                                  JPW1276
 1704 Q(I,IFT)=Q(I+1,IFT)                                               JPW1277
      LP(I+1)=KTEMP                                                     JPW1278
      Z(I+1)=ZTEMP                                                      JPW1279
      DO 1706 IFT=1,NL                                                  JPW1280
 1706 Q(I+1,IFT)= QTEMP(IFT)                                            JPW1281
 1720 CONTINUE                                                          JPW1282
      IF(MDIM-61) 2012,2012,2010                                        JPW1283
 2012 GO TO (1749,1751),IDIR3                                           JPW1284
 1749 DO 1750 I=1,NP                                                    JPW1285
      KTEMP=LP(I)/100                                                   JPW1286
 1750 LP(I)=(LP(I)-KTEMP*100)*100+KTEMP                                 JPW1287
 1751 READ 9,NBP                                                        JPW1288
C    THE NUMBER OF BOUNDARY POINTS (NBP) IS READ                       JPW1289
      PRINT 61
      PRINT 47,NBP                                                      JPW1290
      IF(NBP) 2000,2000,2001                                            JPW1291
 2001 DO 1375 IBP=1,NBP                                                 JPW1292
 1375 READ 10,LBP(IBP),LBPS(IBP),XBP(IBP),YBP(IBP),ZBP(IBP)             JPW1293
C    THE LIST OF BOUNDARY POINT NUMBERS (LBP),THE SIDE ON WHICH THEY LIE (LBPS)  JPW1294
C    AND THE X,Y, AND Z COORDINATES OF EACH BOUNDARY POINT ARE READ
      PRINT 48
      PRINT 49,(LBP(I),LBPS(I),XBP(I),YBP(I),ZBP(I) ,I=1,NBP)           JPW1295
 2000 NS2=2*NS                                                          JPW1296
C    THE CORNER POINTS PREVIOUSLY READ ARE ADDED TO THE LIST OF BOUNDARY POINTS  JPW1297
C    ARE READ INTO THE PROGRAM
      DO 1390 IADDCP=1,NS                                               JPW1298
      JADDCP=IADDCP*2-1+NBP                                             JPW1299
      LBP(JADDCP)=0                                                     JPW1300
      XBP(JADDCP)=CPC(IADDCP,1)                                         JPW1301
      YBP(JADDCP)=CPC(IADDCP,2)                                         JPW1302
      ZBP(JADDCP)=CPC(IADDCP,3)                                         JPW1303
      LBP(JADDCP+1)=0                                                   JPW1304
      XBP(JADDCP+1)=CPC(IADDCP,1)                                       JPW1305
      YBP(JADDCP+1)=CPC(IADDCP,2)                                       JPW1306
      ZBP(JADDCP+1)=CPC(IADDCP,3)                                       JPW1307
      DO 1390 KADDCP=1,NS                                               JPW1308
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 1385 IF(MCONS(3,KADDCP)-MC(IADDCP)) 1387,1386,1387                    JPW1309
 1386 LBPS(JADDCP+1)=MCONS(1,KADDCP)                                   JPW1310
      GO TO 1390                                                       JPW1311
 1387 IF(MCONS(2,KADDCP)-MC(IADDCP)) 1390,1380,1390                    JPW1312
 1380 LBPS(JADDCP)=MCONS(1,KADDCP)                                     JPW1313
 1390 CONTINUE                                                         JPW1314
      IMID=NS+NBS+NS                                                   JPW1315
      INOT=1                                                           JPW1316
      J=1                                                              JPW1317
C   THE AUGMENTED LIST OF BOUNDARY POINTS IS FIRST SORTED INTO GROUPS ACCORDING
C   TO THE SIDE ON WHICH THEY LIE
      DO 1421 ISORT=1,NS                                               JPW1318
      DO 1420 JSORT=J,IMID                                             JPW1319
      IF(MCONS(1,ISORT)-LBPS(JSORT))1420,1410,1420                     JPW1320
 1410 ITLBP=LBP(INOT)                                                  JPW1321
      ITLBPS=LBPS(INOT)                                                JPW1322
      TXBP=XBP(INOT)                                                   JPW1323
      TYBP=YBP(INOT)                                                   JPW1324
      TZBP=ZBP(INOT)                                                   JPW1325
      LBP(INOT)=LBP(JSORT)                                             JPW1326
      LBPS(INOT)=LBPS(JSORT)                                           JPW1327
      XBP(INOT)=XBP(JSORT)                                             JPW1328
      YBP(INOT)=YBP(JSORT)                                             JPW1329
      ZBP(INOT)=ZBP(JSORT)                                             JPW1330
      LBP(JSORT)=ITLBP                                                 JPW1331
      LBPS(JSORT)=ITLBPS                                               JPW1332
      XBP(JSORT)=TXBP                                                  JPW1333
      YBP(JSORT)=TYBP                                                  JPW1334
      ZBP(JSORT)=TZBP                                                  JPW1335
      INOT=INOT+1                                                      JPW1336
 1420 CONTINUE                                                         JPW1337
      J=INOT                                                           JPW1338
      IF(J-IMID) 1421,1421,1422                                        JPW1339
 1421 CONTINUE                                                         JPW1340
C   THE LIST OF BOUNDARY POINTS IS NOW SORTED SO THAT THEY APPEAR IN THE ORDER
C   IN WHICH THEY LIE ON THE BOUNDARY
 1422 DO 1481 IXSOR2=1,IMID                                            JPW1341
      DO 1480 IXSORT=1,IMID                                            JPW1342
      IF(LBPS(IXSORT)-LBPS(IXSORT+1)) 1480,1490,1480                   JPW1343
 1490 JXSORT=LBPS(IXSORT)                                              JPW1344
      DO 1500 IS=1,NS                                                  JPW1345
      IF(MCONS(1,IS)-JXSORT) 1500,1510,1500                            JPW1346
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 1500 CONTINUE                                                          JPW1347
      IF(IXSOR2-1) 1510,1970,1510                                       JPW1348
 1510 DO 1511 I=1,NS                                                    JPW1349
      IF(MC(I)-MCONS(3,IS)) 1512,1513,1512                              JPW1350
 1512 IF(MC(I)-MCONS(2,IS)) 1511,1514,1511                              JPW1351
 1513 ISP=I                                                             JPW1352
      GO TO 1511                                                        JPW1353
 1514 ISN=I                                                             JPW1354
 1511 CONTINUE                                                          JPW1355
      IF(ABSF(SINS(IS))-.707) 1530,1530,1520                            JPW1356
 1530 IF(CPC(ISP,1)-CPC(ISN,1)) 1540,1540,1550                          JPW1357
 1550 IF(XBP(IXSORT)-XBP(IXSORT+1)) 1480,1480,1560                      JPW1358
 1520 IF(CPC(ISP,2)-CPC(ISN,2)) 1580,1580,1570                          JPW1359
 1570 IF(YBP(IXSORT)-YBP(IXSORT+1)) 1480,1480,1560                      JPW1360
 1580 IF(YBP(IXSORT)-YBP(IXSORT+1)) 1560,1480,1480                      JPW1361
 1540 IF(XBP(IXSORT+1)-XBP(IXSORT)) 1480,1480,1560                      JPW1362
 1560 ITLBPS=LBPS(IXSORT)                                               JPW1363
      ITLBP=LBP(IXSORT)                                                 JPW1364
      TXBP=XBP(IXSORT)                                                  JPW1365
      TYBP=YBP(IXSORT)                                                  JPW1366
      TZBP=ZBP(IXSORT)                                                  JPW1367
      LBPS(IXSORT)=LBPS(IXSORT+1)                                       JPW1368
      LBP(IXSORT)=LBP(IXSORT+1)                                         JPW1369
      XBP(IXSORT)=XBP(IXSORT+1)                                         JPW1370
      YBP(IXSORT)=YBP(IXSORT+1)                                         JPW1371
      ZBP(IXSORT)=ZBP(IXSORT+1)                                         JPW1372
      LBPS(IXSORT+1)=ITLBPS                                             JPW1373
      LBP(IXSORT+1)=ITLBP                                               JPW1374
      XBP(IXSORT+1)=TXBP                                                JPW1375
      YBP(IXSORT+1)=TYBP                                                JPW1376
      ZBP(IXSORT+1)=TZBP                                                JPW1377
 1480 CONTINUE                                                          JPW1378
 1481 CONTINUE                                                          JPW1379
      IOPTS=1                                                           JPW1380
C   ADDITIONAL BOUNDARY POINTS ARE NOW ADDED BETWEEN THOSE READ IN SO THAT THE
C   DISTANCE BETWEEN ANY TWO POINTS IS NOT GREATER THAN THE GRID SIZE (H)
 1630 D=SQRTF((XBP(IOPTS)-XBP(IOPTS+1))**2+(YBP(IOPTS)-YBP(IOPTS+1))**2) JPW1381
      IF(LBPS(IOPTS)-LBPS(IOPTS+1)) 1690,1631,1690                      JPW1382
 1631 IF(D-H) 1690,1690,1600                                            JPW1383
 1600 FNO=D/H                                                           JPW1384
      KNO=FNO                                                           JPW1385
      KNO=KNO-1                                                         JPW1386
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      KED=IMID-IOPTS                                                    JPW1387
      DO 1610 K=1,KED                                                   JPW1388
      ICR=IMID-K+KNO+1                                                  JPW1389
      ISCR=IMID-K+1                                                     JPW1390
      LBP(ICR)=LBP(ISCR)                                                JPW1391
      LBPS(ICR)=LBPS(ISCR)                                              JPW1392
      XBP(ICR)=XBP(ISCR)                                                JPW1393
      YBP(ICR)=YBP(ISCR)                                                JPW1394
 1610 ZBP(ICR)=ZBP(ISCR)                                                JPW1395
      IMID=IMID+KNO                                                     JPW1396
      AB=KNO+1                                                          JPW1397
      ICR=IOPTS+KNO+1                                                   JPW1398
      EQUX=(XBP(IOPTS)-XBP(ICR))/AB                                     JPW1399
      EQUY=(YBP(IOPTS)-YBP(ICR))/AB                                     JPW1400
      EQUZ=(ZBP(IOPTS)-ZBP(ICR))/AB                                     JPW1401
      DO 1620 IIN=1,KNO                                                 JPW1402
      BIN=IIN                                                           JPW1403
      ICR=IOPTS+IIN                                                     JPW1404
      LBP(ICR)=0                                                        JPW1405
      LBPS(ICR)=LBPS(IOPTS)                                             JPW1406
      XBP(ICR)=XBP(IOPTS)-BIN*EQUX                                      JPW1407
      YBP(ICR)=YBP(IOPTS)-BIN*EQUY                                      JPW1408
 1620 ZBP(ICR)=ZBP(IOPTS)-BIN*EQUZ                                      JPW1409
      IOPTS=IOPTS+KNO                                                   JPW1410
 1690 IOPTS=IOPTS+1                                                     JPW1411
      IF(IOPTS-IMID) 1630,1640,1640                                     JPW1412
 1640 IMID2=IMID-1                                                      JPW1413
      IF(INTSW-2) 2020,2021,2020                                        JPW1414
 2021 DO 2022 I=1,IMID                                                  JPW1415
      X=XBP(I)-XORIG                                                    JPW1416
      Y=YBP(I)-YORIG                                                    JPW1417
      IF(COE1-.9) 2050,2050,2051                                        JPW1418
 2050 ZBP(I)=SQRTF(COE(1)*Y**3+COE(2)*X*Y*Y+COE(3)*Y*X*X+COE(4)*X**3+COE JPW1419
     1(5)*Y**2+COE(6)*X*Y+COE(7)*X**2+COE(8)*Y+COE(9)*X+COE(10))        JPW1420
      GO TO 2022                                                        JPW1421
 2051 ZBP(I)=  (COE(1)*Y**3+COE(2)*X*Y*Y+COE(3)*Y*X*X+COE(4)*X**3+COE(5) JPW1422
     1*Y**2+COE(6)*X*Y+COE(7)*X**2+COE(8)*Y+COE(9)*X+COE(10))           JPW1423
 2022 CONTINUE                                                          JPW1424
 2020 ISCH=1                                                            JPW1425
C   THE FINAL LIST OF BOUNDARY POINTS IS NOW CHECKED TO MAKE CERTAIN THAT THEY
C   LIE ON THE STRAIGHT LINE JOINING THE TWO CORNER POINTS WHICH DEFINE THE SIDE
C   WITH WHICH THEY ARE ASSOCIATED
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      DO 1650 I=1,IMID2                                                 JPW1426
      IF(LBPS(I)-LBPS(I+1)) 1660,1670,1660                              JPW1427
 1670 IF(LBP(I)) 1673,1650,1673                                         JPW1428
 1673 DO 1671 J=1,NS                                                    JPW1429
      IF(MCONS(2,ISCH)-MC(J)) 1671,1672,1671                            JPW1430
 1671 CONTINUE                                                          JPW1431
 1672 CHEC=(XBP(I)-CPC(J,1))/SQRTF((CPC(J,1)-XBP(I))**2+(CPC(J,2)-YBP(I) JPW1432
     1)**2)                                                             JPW1433
      IF(ABSF(CHEC-COSS(ISCH))-.100) 1650,1650,1980                     JPW1434
C   ADDRESS 1980 IS AN ERROR CODE FOR THESE BOUNDARY POINTS NOT LYING ON THE
C           PROJECTED SIDE
 1660 ISCH=ISCH+1                                                       JPW1435
 1650 CONTINUE                                                          JPW1436
      I=MATCH(LIST,K,1)                                                 JPW1437
      IF(I-5) 1651,1652,1651                                            JPW1438
 1652 IF(K-7) 1654,1653,1653                                            JPW1439
 1654 PRINT 1656                                                        JPW1440
      INEXT=2                                                           JPW1441
      GO TO 1653                                                        JPW1442
 1651 IEXQ=1                                                            JPW1443
      PRINT 1657                                                        JPW1444
      PRINT 12                                                          JPW1445
 1658 I=MATCH(LIST,K,1)                                                 JPW1446
      IF(I-5) 1658,1659,1658                                            JPW1447
 1659 IF(K-7) 1661,1658,1658                                            JPW1448
 1661 GO TO 1001                                                        JPW1449
 1653 IF(IEXQ) 1700,1700,1710                                           JPW1450
C   A CHECK IS NOW DONE ON THE POINTER IEXQ TO ASCERTAIN WHETHER ANY ERRORS HAVE
C   BEEN ENCOUNTERED IN THE SUPPLIED DATA.   IF SO THE EXECUTION IS DELETED.
 1700 PRINT 21                                                          JPW1451
      PRINT 11                                                          JPW1452
      LX=1                                                              JPW1459
      CALL CHAIN (2,B1)                                                 JPW1460
 1710 PRINT 12                                                          JPW1461
      GO TO 800                                                         JPW1462
C   THE LIST OF ERROR CODES FOLLOWS
 1900 IEXQ=1                                                            JPW1463
      PRINT 13                                                          JPW1464
      DO 1901 I=1,NSIDEC                                                JPW1465
      ICR=JSORT-I+1                                                     JPW1466
 1901 PRINT 18,MCONS(1,ICR)                                             JPW1467
      GO TO 1050                                                        JPW1468
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1910 IEXQ=1                                                    JPW1469
     PRINT 14                                                  JPW1470
     GO TO 1070                                                JPW1471
1930 IEXQ=1                                                    JPW1472
     PRINT 15,MCONS(ITWICE,JTWICE)                             JPW1473
     GO TO 1100                                                JPW1474
1940 IEXQ=1                                                    JPW1475
     PRINT 16,MCONS(ITWICE,JTWICE)                             JPW1476
     GO TO 1100                                                JPW1477
1950 IEXQ=1                                                    JPW1478
     PRINT 17                                                  JPW1479
     IE=NSC(JCLOSE)                                            JPW1480
     IBCE=0                                                    JPW1481
     DO 1951 I=1,IE                                            JPW1482
1951 IBCE=IBCE+NSC(I)                                          JPW1483
     IBCS=IBCE-NSC(IE)+1                                       JPW1484
     DO 1952 J=IBCS,IBCE                                       JPW1485
1952 PRINT 18,MCONS(I,J)                                       JPW1486
     GO TO 1120                                                JPW1487
1960 IEXQ=1                                                    JPW1488
     PRINT 19,MC(ICPRED)                                       JPW1489
     GO TO 1130                                                JPW1490
1970 IEXQ=1                                                    JPW1491
     PRINT 19,JXSORT                                           JPW1492
     GO TO 1510                                                JPW1493
1980 IEXQ=1                                                    JPW1494
     PRINT 20,LBP(I)                                           JPW1495
     GO TO 1650                                                JPW1496
2005 PRINT 2008                                                JPW1497
     IEXQ=1                                                    JPW1498
     GO TO 2004                                                JPW1499
2007 PRINT 2009                                                JPW1500
     NL=1                                                      JPW1501
     GO TO 2006                                                JPW1502
2010 PRINT 2011                                                JPW1503
     IEXQ=1                                                    JPW1504
     GO TO 2012                                                JPW1505
   1 FORMAT (2I6)                                              JPW1506
   2 FORMAT (3I6)                                              JPW1507
   3 FORMAT (1I6)                                              JPW1508
   4 FORMAT (I6,3F12.4)                                        JPW1509
   5 FORMAT (2I6)                                              JPW1510
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 6 FORMAT (I6,F12.4,3F12.4)                                             JPW1511
 7 FORMAT (1F12.4)                                                      JPW1512
 8 FORMAT (1F12.4)                                                      JPW1513
 9 FORMAT (1I6)                                                         JPW1514
10 FORMAT (2I6,3F12.4)                                                  JPW1515
11 FORMAT(///10X,50HNO CONTRADICTIONS ENCOUNTERED IN THE SUPPLIED DAT JPW1516
  1A//5X,31HEXECUTION PHASE WILL NOW BEGIN.///)                         JPW1517
12 FORMAT(10X,54HERRORS,AS LISTED,HAVE BEEN FOUND IN THE SUPPLIED DAT JPW1518
  1A.//34H PLEASE CORRECT THESE AND RESUBMIT//57H EXECUTION PHASE DEL JPW1519
  2ETED IN ANTICIPATION OF YOUR NEXT RUN//11H THANK YOU.////////1H1)  JPW1520
13 FORMAT(5X,59HTHE FOLLOWING BOUNDARY HAS AN INSUFFICIENT NUMBER OF  JPW1521
  1SIDES.//)                                                            JPW1522
14 FORMAT(5X,67HTHE NC GIVEN IS INCONSISTENT WITH THE SUPPLIED CONNEC JPW1523
  1TIVITY MATRIX./////)                                                 JPW1524
15 FORMAT(5X,21HTHE SAME SIDE NUMBER,I2,24H,IS USED MORE THAN ONCE.// JPW1525
  1///)                                                                 JPW1526
16 FORMAT(5X,29HTHE SAME CORNER POINT NUMBER,I2,24H,IS USED MORE THAN JPW1527
  1 ONCE./////)                                                         JPW1528
17 FORMAT(5X,39HTHE FOLLOWING BOUNDARY IS DISCONTINUOUS//5X,43HTHIS B JPW1529
  1OUNDARY IS COMPRISED OF SIDE NUMBERS-//)                             JPW1530
18 FORMAT(30X,I6/)                                                      JPW1531
19 FORMAT(5X,17HTHE SIDE NUMBERED,I4,84H MENTIONED IN THE LIST OF BOU JPW1532
  1NDARY POINTS,DOES NOT APPEAR IN THE CONNECTIVITY TABLE.//)           JPW1533
20 FORMAT(5X,15HBOUNDARY POINT I3,45H DOES NOT LIE ON THE PROJECTED B JPW1534
  1OUNDARY LINE./////)                                                  JPW1535
21 FORMAT (1X,////)                                                     JPW1536
30 FORMAT (6HMCONS=,3I3/)                                               JPW1537
31 FORMAT (4HNSC=I3)                                                    JPW1538
32 FORMAT (F12.4)                                                       JPW1539
33 FORMAT (/F12.4,I6/)                                                  JPW1540
35 FORMAT (12A6)                                                        JPW1541
36 FORMAT(1H1,15X,12HPROBLEM NAME//)                                    JPW1542
37 FORMAT (20X,12A6//)                                                  JPW1543
38 FORMAT (F12.4)                                                       JPW1544
40 FORMAT(2F12.4)                                                       JPW1545
41 FORMAT (5X,25HNUMBER OF INTERNAL POINTS,I4,10X,28HNUMBER OF LOADIN JPW1546
  1G CONDITIONS,I3//)                                                   JPW1547
42 FORMAT (5X,13HGRID SPACING,F8.3//)                                   JPW1548
43 FORMAT (10X,8HAT POINT,6X,18HELEVATION OF POINT,6X,17HPROJECTED LO JPW1549
  1ADING/ 11X,6HNUMBER,9X,15HABOVE X Y PLANE,11X,9HAT  POINT///)        JPW1550
44 FORMAT(/12X,I4, 8X,F12.4,11X,3F12.4)                                 JPW1551
45 FORMAT(////5X,86HTHE ELEVATION OF THE SHELL ABOVE THE X Y PLANE HA JPW1552
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     1S BEEN CALCULATED FROM THE POLYNOMIAL//3X,F8.3,5HY*Y*Y,F8.3,5HY*Y*  JPW1553
     2X,F8.3,5HY*X*X,F8.3,5HX*X*XF8.3,3HY*Y,F8.3,3HY*X,F8.3,3HX*X,F8.3,1  JPW1554
     3HY,F8.3,1HX,F8.3//10X,10HALL TO THE,F8.3,6H POWER/25X,47HNOTE  ALL  JPW1555
     4 SIGNS ARE +VE. UNLESS SHOWN OTHERWISE//)                           JPW1556
  46 FORMAT (5X,65HTHIS POLYNOMIAL HAS BEEN TAKEN ABOUT AN ORIGIN WHICH  JPW1557
     1 WOULD BE (X=,F8.3,4H, Y=,F8.3,1H)38H ABOUT THE ORIGIN FOR INTERNA JPW1558
     2L POINTS./////)                                                     JPW1559
  47 FORMAT (5X,32HNUMBER OF BOUNDARY POINTS EQUALS,I4//)                 JPW1560
  48 FORMAT (10X,8HBOUNDARY,10X,8HON  SIDE,10X,1HX,15X,1HY,15X,1HZ/ 8X,  JPW1561
     112HPOINT NUMBER,9X,6HNUMBER,6X,11HCOORDINATES,5X,11HCOORDINATES,5X JPW1562
     2,11HCOORDINATES///)                                                 JPW1563
  49 FORMAT(11X,I3,15X,I3, 5X,F12.3,4X,F12.3,4X,F12.3//)                  JPW1564
  51 FORMAT (/2I3,3F12.4)                                                 JPW1565
  52 FORMAT (12X,I3//)                                                    JPW1566
  56 FORMAT(////15X,19HCONNECTIVITY MATRIX//)                             JPW1567
  57 FORMAT(////15X,21HLIST OF CORNER POINTS,//5X,23HNUMBER OF CORNER P JPW1568
     1OINTS,I4/)                                                          JPW1569
  58 FORMAT (14X,I3,10X,F12.4,7X,F12.4,7X,F12.4//)                        JPW1570
  59 FORMAT(10X,12HCORNER POINT,13X,1HX,18X,1HY,18X,1HZ/13X,6HNUMBER11X JPW1571
     1,11HCOORDINATES,8X,11HCOORDINATES,8X,11HCOORDINATES///)             JPW1572
  60 FORMAT (1H1,15X,23HLIST OF INTERNAL POINTS,//)                       JPW1573
  61 FORMAT (1H1,15X,23HLIST OF BOUNDARY POINTS,//)                       JPW1574
 936 FORMAT (5X,85HTHE CONTROL CARD, WHICH SHOULD BE THIRD IN THE DATA, JPW1575
     1IS MISSING OR WRONGLY FORMULATED.//10X,42HANALYSIS USING DISCRETE  JPW1576
     2POINTS IS ASSUMED./////)                                            JPW1577
 961 FORMAT (15X,53HDESIGN THE MIDSURFACE OF THE SHELL AS SPECIFIED BEL JPW1578
     1OW//)                                                               JPW1579
 971 FORMAT (15X,59HANALYZE A SHELL WHOSE MIDSURFACE IS SPECIFIED BY A  JPW1580
     1FUNCTION//)                                                         JPW1581
 981 FORMAT (15X,64HANALYZE A SHELL WHOSE MIDSURFACE IS SPECIFIED AT DI JPW1582
     1SCRETE POINTS//)                                                    JPW1583
 982 FORMAT(/10X,20HPROBLEM TO BE SOLVED/ )                              JPW1584
1004 FORMAT (5X,22HNUMBER OF SIDES EQUALS,I3,10X,25HNUMBER OF CONTOURS  JPW1585
     1EQUALS,I3)                                                          JPW1586
1007 FORMAT(/5X,25HFROM CORNER POINT NUMBER 15I6)                         JPW1587
1008 FORMAT(/6X,22HTO CORNER POINT NUMBER,2X,15I6)                        JPW1588
1009 FORMAT(/11X,11HSIDE NUMBER,8X,15I6)                                  JPW1589
1012 FORMAT (46X,4HFROM17X,2HTO//20X,11HSIDE NUMBER11X,12HCORNER POINT, JPW1590
     18X,12HCORNER POINT//45X,6HNUMBER,14X,6HNUMBER///)                   JPW1591
1014 FORMAT (24X,I3,19X,I3,17X,I3//)                                      JPW1592
1656 FORMAT (/13X,88HTHE FINAL CARD,WHICH SHOULD BE A PROBLEM SPECIFIED JPW1593
     1 CARD,IS MISSING OR WRONGLY FORMULATED//15X,27HHOWEVER EXECUTION C JPW1594
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    2ONTINUES//)                                                        JPW1595
1657 FORMAT (/10X,36HMORE DATA IS SUPPLIED THAN REQUIRED.//)            JPW1596
2008 FORMAT (5X,59HTHE NUMBER OF INTERNAL POINTS IS TOO L .GE FOR THIS  JPW1597
    1PROGRAM//)                                                         JPW1598
2009 FORMAT (5X,80HTHE NUMBER OF LOADING CONDITIONS IS 1. LARGE.ONLY T  JPW1599
    1HE FIRST ONE HAS BEEN TAKEN.//)                                    JPW1600
2011 FORMAT (5X,117HTHE MINIMIUM OVERALL DIMENSION OF THE X OR Y DIRECT JPW1601
    1ION IS TOO LARGE FOR THIS PROGRAM.IT MUST BE LESS THAN 16*GRIDSIZE JPW1602
    2//)                                                                JPW1603
2013 FORMAT (20X,39HPRESCRIBED PROJECTED STRESS RESULTANT =,F8.2//)     JPW1604
     END                                                                JPW1605
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*     CHAIN (2,R1)
*     LIST8                                                             JPW2063
*     LABEL                                                             JPW2064
CPART2                                                                  JPW2065
C   PHASE 2  THIS PHASE ASSEMBLES THE DIFFERENCE EQUATION AT EACH POINT
      DIMENSION COE(10),TITLE(12),MCONS(3,100),MC(100),CPC(100,3),      JPW2066
     1LBP(500),LBPS(500),XBP(500),YBP(500),ZBP(500),COSS(100),SINS(100), JPW2067
     2LP(561),LPC(561),Z(561),Q(561,3)                                  JPW2068
      COMMON COE,TITLE,MCONS,MC,CPC,LBP,LBPS,XBP,YBP,ZBP,COSS,SINS,LP,LP JPW2069
     1C,Z,Q,INTSW,IEXQ,INEXT,NS,NC,NP,NL  ,IMID,MDIM,H,COE1,XORIG,YORIG JPW2070
      COMMON AN,LX,IPRINT                                               JPW2071
      DIMENSION KSTAR(10),ZBC(6),AZ(10,42),AF(10,3),KZ(37),IA(12),T(10), JPW2072
     1  REXY(10),REYY(10),RDF(10),A1(61,61),A2(61,61),AO(10,37),KZO(37), JPW2073
     2  RET(10,5),REXX(10),KZ1(10)                                      JPW2074
      REWIND 10                                                         JPW2076
      REWIND 11                                                         JPW2077
      REWIND 12                                                         JPW2078
      GO TO (4000,4000,4001),INTSW                                      JPW2079
 4001 DO 4002 I=1,NP                                                    JPW2080
 4002 Q(I,3)=Q(I,1)                                                     JPW2081
 4000 CALL CLGRID (LP,NP,LPC)                                           JPW2082
C   SUBROUTINE CLGRID CLASSIFIES EACH GRID POINT DEPENDING ON HOW MANY OF THE
C   EIGHT SURROUNDING RELATIVE POINTS ARE IN THE LIST OF INTERIOR POINTS
C   LP=LIST OF INTERIOR POINTS
C   NP IS THE NUMBER OF INTERIOR POINTS
C   LPC=1,2 OR 3 ACCORDING TO THE CLASSIFICATION OF GRID POINT
      NOM=NP/MDIM+1                                                     JPW2083
      DO 8200 MAT=1,NOM                                                 JPW2084
      DO 8000 I=1,MDIM                                                  JPW2085
      DO 8000 J=1,MDIM                                                  JPW2086
      A1(I,J)=0.0                                                       JPW2087
 8000 A2(I,J)=0.0                                                       JPW2088
      DO 8170 MROW=1,MDIM                                               JPW2089
      DO 3010 J=1,10                                                    JPW2090
      REXX(J)=0.0                                                       JPW2091
      REXY(J)=0.0                                                       JPW2092
      REYY(J)=0.0                                                       JPW2093
C   REXX, REXY, REYY ARE CLEARED
 3010 RDF(J)=0.0                                                        JPW2094
      IROW=MDIM*(MAT-1)+MROW                                            JPW2095
      ITWO=IROW                                                         JPW2096
      IF(IROW-NP) 8005,8005,8210                                        JPW2097
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 8005 DO 3050 I=1,37                                                    JPW2098
 3050 KZ(I)=0                                                           JPW2099
C   MATRICES AF AND AZ ARE CLEARED
      DO 3031 I=1,10                                                    JPW2100
      DO 3031 J=1,42                                                    JPW2101
 3031 AZ(I,J)=0.0                                                       JPW2102
      K=2                                                               JPW2103
      AZ(1,1)=1.0                                                       JPW2104
      KZ(1)=LP(ITWO)                                                    JPW2105
      IF(LPC(ITWO)-2) 3060,3075,3080                                    JPW2106
 3080 DO 3090 JSIDE=1,NS                                                JPW2107
      CALL DIST(CPC,H,LP,ITWO,MCONS,JSIDE,D,XD,YD,X1,X2,Y1,Y2,X3,Y3,NS,M JPW2108
     1C)                                                                JPW2109
C   SUBROUTINE DIST CALCULATES DISTANCE OF A POINT, ITWO, FROM A SIDE, JSIDE
C   THIS ROUTINE IS CALLED FOR EACH SIDE
C   CPC=THE CORNER POINT COORDINATE MATRIX
C   H=THE GRID SIZE
C   LP=LIST OF POINTS
C   ITWO=THE ADDRESS OF THE POINT IN THE LIST OF POINTS
C   MCONS=CONNECTIVITY MATRIX
C   JSIDE=THE ADDRESS OF THE SIDE IN QUESTION FROM
C   JSIDE=THE ADDRESS OF THE SIDE IN QUESTION IN THE CONNECTIVITY MATRIX
C   D=THE DISTANCE OF THE POINT FROM THE SIDE
C   XD,YD ARE THE COORDINATES OF THE JUNCTION POINT OF THE NORMAL AND THE SIDE
C   X1,X2,Y1,Y2, ARE THE CORNER POINT COORDINATES FOR THE SIDE
C   NS=NUMBER OF SIDES
C   MC=THE VECTOR OF CORNER POINT NUMBERS
      IF(D-H*1.414)3100,3090,3090                                       JPW2110
C   IF THE POINT IS CLOSER THAN H*SQRT (2),1 BOUNDARY POINTS ARE ASSEMBLED
 3100 KD=1                                                              JPW2111
 3110 IF(KD-2) 3120,3130,3140                                           JPW2112
 3130 XD=XD+H*COSS(JSIDE)                                               JPW2113
      YD=YD+SINS(JSIDE)*H                                               JPW2114
      GO TO 3120                                                        JPW2115
 3140 XD=XD-H*COSS(JSIDE)*2.0                                           JPW2116
      YD=YD-H*SINS(JSIDE)*2.0                                           JPW2117
 3120 IF(ABSF(SINS(JSIDE))-.707) 3180,3180,3190                         JPW2118
 3180 IF(XD-X1)3200,3210,3210                                           JPW2119
 3200 IF(XD-X2)3220,3230,3230                                           JPW2120
 3210 IF(XD-X2)3230,3220,3220                                           JPW2121
 3190 IF(YD-Y1)3240,3250,3250                                           JPW2122
 3240 IF(YD-Y2)3220,3230,3230                                           JPW2123
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 3250 IF(YD-Y2)3230,3220,3220                                           JPW2124
 3220 IF(D-H*1.01) 3260,3260,3090                                       JPW2125
C    IF THE POINT IS CLOSER THAN H,3 BOUNDARY POINTS ARE ASSEMBLED
C    THIS IS DONE BY OVERSTORING THE ORIGINAL VALUES OF XD AND YD WITH THOSE
 3260 KD=KD+1                                                           JPW2126
      IF(KD-3) 3110,3110,3090                                           JPW2127
 3230 ALFA=(XD-X3)/H                                                    JPW2128
      BETA=(YD-Y3)/H                                                    JPW2129
      CALL TSF(ALFA,BETA,T)                                             JPW2130
C    SUBROUTINE TSF CALCULATES A TWO DIMENSIONAL TAYLOR SERIES
C    ALFA=THE DISTANCE OF XD FROM THE CENTRAL POINT
C    ALFA=THE TAYLOR SERIES PARAMETER IN THE X DIRECTION
C    BETA=THE TAYLOR SERIES PARAMETER IN THE Y DIRECTION
C    THE VECTOR T IS THE RETURNED TAYLOR SERIES TO THE FIRST TEN TERMS
 3269 DO 3270 IT=1,10                                                   JPW2131
 3270 AZ(IT,K)=T(IT)                                                    JPW2132
 3301 KZ(K)=K-1                                                         JPW2133
C    KF,AND KZ ARE POINTERS WHICH WILL CONTAIN THE ADDRESSES IN LP OF THE POINTS
C    REFERRED TO BY THE RESPECTIVE ELEMENTS OF MATRICES AF AND AZ
      CALL FINDZD(MCONS,LBPS,XBP,YBP,ZBP,SINS,XD,YD,IMID,JSIDE,ZD)      JPW2134
C    SUBROUTINE FINDZD RETURNS THE VALUE OF Z FOR ANY XD AND YD
C    MCONS=THE CONNECTIVITY MATRIX
C    LBPS=THE SIDE NUMBER WITH WHICH XD AND YD ARE ASSOCIATED
C    XBP,YBP, AND ZBP ARE THE X,Y, AND Z COORDINATES OF THE BOUNDARY POINTS
C    SINS IS THE VECTOR OF SINES FOR THE SIDES
C    XD,YD ARE THE X AND Y COORDINATES OF THE POINT WHERE Z IS TO BE CALCULATED
C    IMID=THE NUMBER OF BOUNDARY POINTS
C    JSIDE IS THE ADDRESS OF THE SIDE IN QUESTION IN THE CONNECTIVITY MATRIX
C    ZD=THE RETURNED VALUE OF Z AT POINT XD,YD
      ZBC(K-1)=ZD                                                       JPW2135
      K=K+1                                                             JPW2136
      GO TO 3220                                                        JPW2137
 3090 CONTINUE                                                          JPW2138
      NBC=K-1                                                           JPW2139
C    NBC=THE NUMBER OF BOUNDARY CONDITIONS ASSEMBLED AT POINT LP (ITWO)
 3075 M=2                                                               JPW2140
C    M=THE RELATIVE  NUMBER OF ANY POINT WITH RESPECT TO THE CENTRAL POINT
 3330 IF(M-49)3310,3310,3440                                            JPW2141
 3310 NOCP=LP(ITWO)                                                     JPW2142
      CALL  RELABS(M,NOCP)                                              JPW2143
C    SUBROUTINE RELABS RETURNS THE ABSOLUTE NUMBER  FOR ANY SUPPLIED RELATIVE
C    NUMBER , GIVEN THE ABSOLUTE NUMBER OF THE CENTRAL POINTS
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C    M=RELATIVE NUMBER
C    NOCP IS THE ABSOLUTE NUMBER AS GIVEN AND AS RETURNED
      DO 3350 INLP=1,NP                                                 JPW2144
      IF(LP(INLP)-NOCP) 3350,3360,3350                                  JPW2145
 3350 CONTINUE                                                          JPW2146
      M=M+1                                                             JPW2147
      GO TO 3330                                                        JPW2148
 3360 CALL ALBETA(M,ALFA,BETA)                                          JPW2149
C    SUBROUTINE ALBETA RETURNS VALUES OF  ALFA AND BETA FOR ANY RELATIVE NUMBER
      CALL TSF(ALFA,BETA,T)                                             JPW2150
 3361 DO 3370 IT=1,10                                                   JPW2151
 3370 AZ(IT,K)=T(IT)                                                    JPW2152
 3390 KZ(K)=NOCP                                                        JPW2153
      IF(LPC(ITWO)-2) 3410,3411,3410                                    JPW2154
 3411 IF(K-10)3430,3440,3440                                            JPW2155
 3410 IF(K-37) 3430,3440,3440                                           JPW2156
 3430 K=K+1                                                             JPW2157
      M=M+1                                                             JPW2158
      GO TO 3330                                                        JPW2159
 3440 GO TO (4010,4010,4020),INTSW                                      JPW2160
C    THE RIGHT HANDS SIDES OF THE AUGMENTED MATRICES AZ AND AF ARE MOVED IN
C    NOTE THAT THE MATRIX HAS BEEN  PREVIOUSLY CLEARED
 4020 AZ(4,38)=1.0                                                      JPW2161
      AZ(6,38)=1.0                                                      JPW2162
      AZ(2,41)=1.0                                                      JPW2163
      AZ(3,42)=1.0                                                      JPW2164
      GO TO 4030                                                        JPW2165
 4010 AZ(4,38)=1.0                                                      JPW2166
      AZ(5,39)=1.0                                                      JPW2167
      AZ(6,40)=1.0                                                      JPW2168
      AZ(2,41)=1.0                                                      JPW2169
      AZ(3,42)=1.0                                                      JPW2170
 4030 DO 210 I=1,10                                                     JPW2171
      DO 210 J=1,37                                                     JPW2172
      AO(I,J)=AZ(I,J)                                                   JPW2173
  210 KZO(J)=KZ(J)                                                      JPW2174
 3449 NBC=1                                                             JPW2175
 3448 CALL JUDY (AZ,10,37,KZ,NBC,LP,ITWO,IEXQ,5)                        JPW2181
C    SUBROUTINE JUDY SOLVES FOR THE FINITE DIFFERENCE MOLECULE FIRST FOR THE Z
C    PHASE AND THEN USES THE RESULTS IN SOLVING IN THE F PHASE
C    KZ IS THE VECTOR OF UNKNOWNS FOR THE MATRIX
 3460 DO 220 I=1,10                                                     JPW2182
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      DO 220 J=1,5                                                      JPW2183
  220 RET(I,J)=AZ(I,J+37)                                               JPW2184
      IF(IPRINT) 9009,9010,9009                                         JPW2185
 9010 PRINT 3451,LP(ITWO)                                               JPW2186
      DO 3542 I=38,42                                                   JPW2187
 3542 PRINT 3453,(AZ(J,I),J=1,10)                                       JPW2188
      PRINT 3457,(KZ(I),I=1,10)                                         JPW2189
 9009 CALL CHECK (AO,RET,KZ,KZO,10,37,5,IPRINT,LP,ITWO)                 JPW2190
      DO 9006 I=1,10                                                    JPW2191
      DO 9007 J=41,42                                                   JPW2192
 9007 AZ(I,J)=AZ(I,J)/H                                                 JPW2193
      DO 9006 J=38,40                                                   JPW2194
 9006 AZ(I,J)=AZ(I,J)/H**2                                              JPW2195
      DO 4090 I=1,3                                                     JPW2196
      DO 4090 J=1,10                                                    JPW2197
      K=37+I                                                            JPW2198
 4090 AF(J,I)=AZ(J,K)                                                   JPW2199
      DO 3400 I=1,10                                                    JPW2200
 3400 KSTAR(I)=KZ(I)                                                    JPW2201
      GO TO (3501,3502,4040),INTSW                                      JPW2202
 4040 ITEMP=KZ(1)                                                       INSERT 1
      KZ(1)=KZ(2)                                                       INSERT 2
      KZ(2)=ITEMP                                                       INSERT 3
      DO 4041 I=38,42                                                   INSERT 4
      TEMP=AZ(1,I)                                                      INSERT 5
      AZ(1,I)=AZ(2,I)                                                   INSERT 6
 4041 AZ(2,I)=TEMP                                                      INSERT 7
      KSTAR(1)=KZ(1)                                                    INSERT 8
      KSTAR(2)=KZ(2)                                                    INSERT 9
      DO 4050 IZ=1,10                                                   JPW2203
      IF(KZ(IZ)-6) 4060,4060,4050                                       JPW2204
C   NOTE    DEPENDING ON WHETHER THE COLUMN ASSEMBLED REFERS TO A POINT ON THE
C   BOUNDARY OR AN INTERNAL POINT THE VALUE OF RDE IS CALCULATED IN DIFFERENT
C   WAYS    SEE FLOW CHARTS
 4060 I=KZ(IZ)                                                          JPW2205
      DO 4070 JZ=38,42                                                  JPW2206
      AZ(IZ,JZ)=AZ(IZ,JZ)*ZBC(I)                                        JPW2207
      IF(IZ-1) 4080,4070,4080                                           JPW2208
 4080 AZ(1,JZ)=AZ(1,JZ)+AZ(IZ,JZ)                                       JPW2209
 4070 CONTINUE                                                          JPW2210
 4050 CONTINUE                                                          JPW2211
 4100 IF(KSTAR(1)-6) 4130,4130,4140                                     JPW2212
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4130 Q(ITWO,1)=Q(ITWO,3)-AZ(1,38)                                       JPW2213
4140 DO 4150 I=1,10                                                     JPW2214
4150 RDF(I)=AZ(I,38)                                                    JPW2215
     WRITE TAPE 11,(KSTAR(I),AZ(I,41),AZ(I,42),I=1,10)                  JPW2216
     GO TO 8010                                                         JPW2217
3501 DO 3472 IZ=1,10                                                    JPW2218
     IF(KZ(IZ)) 3509,3471,3509                                          JPW2219
3509 IF(KZ(IZ)-6) 3510,3510,3520                                        JPW2220
3510 I=KZ(IZ)                                                           JPW2221
     DO 3540 JZ=38,42                                                   JPW2222
     AZ(IZ,JZ)=AZ(IZ,JZ)*ZBC(I)                                         JPW2223
     IF(IZ-1) 3530,3540,3530                                            JPW2224
3530 AZ(1,JZ)=AZ(1,JZ)+AZ(IZ,JZ)                                        JPW2225
3540 CONTINUE                                                           JPW2226
     GO TO 3472                                                         JPW2227
3520 DO 3550 ILP=1,NP                                                   JPW2228
     IF(KZ(IZ)-LP(ILP)) 3550,3560,3550                                  JPW2229
3550 CONTINUE                                                           JPW2230
3560 DO 3470 JZ=38,42                                                   JPW2231
     AZ(IZ,JZ)=AZ(IZ,JZ)*Z(ILP)                                         JPW2232
     IF(IZ-1) 3580,3470,3580                                            JPW2233
3580 AZ(1,JZ)=AZ(1,JZ)+AZ(IZ,JZ)                                        JPW2234
3470 CONTINUE                                                           JPW2235
3472 CONTINUE                                                           JPW2236
 101 IF(IPRINT) 3471,9013,3471                                          JPW2237
9013 PRINT 7015,(AZ(1,I),I=38,42)                                       JPW2238
     GO TO 3471                                                         JPW2239
3502 IY=LP(ITWO)/100                                                    JPW2240
     IX=LP(ITWO)-IY*100                                                 JPW2241
     Y=IY                                                               JPW2242
     X=IX                                                               JPW2243
     Y=Y*H                                                              JPW2244
     X=X*H                                                              JPW2245
     X=X-XORIG                                                          JPW2246
     Y=Y-YORIG                                                          JPW2247
     Z1=Z(ITWO)                                                         JPW2248
     AZ(1,38)=COE(4)*6.*X+2.*COE(3)*Y+2.*COE(7)                         JPW2249
     AZ(1,39)=2.*COE(3)*X+2.*COE(2)*Y+COE(6)                            JPW2250
     AZ(1,40)=2.*COE(2)*X+6.*COE(1)*Y+2.*COE(5)                         JPW2251
     AZ(1,41)=COE(4)*X*X*3.+2.*X*Y*COE(3)+Y*Y*COE(2)+2.*X*COE(7)+COE(6) JPW2252
    1*Y+COE(9)                                                          JPW2253
     AZ(1,42)=COE(3)*X*X+2.*COE(2)*Y*X+3.*COE(1)*Y*Y+COE(6)*X+2.*COE(5) JPW2254
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     1*Y+COE(8)                                                         JPW2255
      IF(COE1-.9) 3503,3471,3471                                        JPW2256
3503  Z1=Z1**2                                                          JPW2257
      AZ(1,38)=(SQRTF(Z1)*.5*AZ(1,38)-.25*AZ(1,41)*AZ(1,41)/SQRTF(Z1))/Z JPW2258
     11                                                                 JPW2259
      AZ(1,39)=(SQRTF(Z1)*.5*AZ(1,39)-.25*AZ(1,41)*AZ(1,42)/SQRTF(Z1))/Z JPW2260
     11                                                                 JPW2261
      AZ(1,40)=(SQRTF(Z1)*.5*AZ(1,40)-.25*AZ(1,42)*AZ(1,42)/SQRTF(Z1))/Z JPW2262
     11                                                                 JPW2263
      AZ(1,41)=AZ(1,41)*.5/SQRTF(Z1)                                    JPW2264
      AZ(1,42)=AZ(1,42)*.5/SQRTF(Z1)                                    JPW2265
3471  AZ(1,39)=-2.0*AZ(1,39)                                            JPW2266
3704  DO 3480 IZ=1,10                                                   JPW2267
      RFYY(IZ)=AF(IZ,3)                                                 JPW2268
      RFXY(IZ)=AF(IZ,2)                                                 JPW2269
3480  RFXX(IZ)=AF(IZ,1)                                                 JPW2270
3713  DO 3590 IF=1,3                                                    JPW2271
      KS=41-IF                                                          JPW2272
      DO 3590 JF=1,10                                                   JPW2273
3590  AF(JF,IF)=AF(JF,IF)*AZ(1,KS)                                      JPW2274
      ZX=AZ(1,41)                                                       JPW2275
      ZY=AZ(1,42)                                                       JPW2276
      DO 3600 IRDF=1,10                                                 JPW2277
3600  RDF(IRDF)=AF(IRDF, 1)+AF(IRDF, 2)+AF(IRDF, 3)                     JPW2278
      WRITE TAPE 11,(KSTAR(I),RFXX(I),RFXY(I),RFYY(I),I=1,10),ZX,ZY     JPW2279
8010  DO 8160 JROW=1,10                                                 JPW2280
      IF(KSTAR(JROW)-6) 8160,8160,8015                                  JPW2281
8015  DO 8020 I=1,NP                                                    JPW2282
      IF(KSTAR     (JROW)-LP(I)) 8020,8030,8020                         JPW2283
8020  CONTINUE                                                          JPW2284
8030  IF(I-(MAT-1)*MDIM) 8040,8040,8050                                 JPW2285
8040  J=I-(MAT-2)*MDIM                                                  JPW2286
      A1(MROW,J)=RDF(JROW)                                              JPW2287
      GO TO 8160                                                        JPW2288
8050  IF(I-MAT*MDIM) 8060,8060,8070                                     JPW2289
8060  J=I-(MAT-1)*MDIM                                                  JPW2290
      A2(MROW,J)=RDF(JROW)                                              JPW2291
      GO TO 8160                                                        JPW2292
8070  J=I-MAT*MDIM                                                      JPW2293
      A1(MROW,J)=RDF(JROW)                                              JPW2294
8160  CONTINUE                                                          JPW2295
      GO TO 8170                                                        JPW2296
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 3060 GO TO (3063,3064,4200),INTSW                                      JPW2297
C    IF LPC=1, THE FINITE DIFFERENT MOLECULE DOES  NOT OVERLAP THE BOUNDARY AT
C     ALL AND RDE, ZXX,ZYY,ZXY,ZX, AND ZY CAN BE CALCULATED BY THE USUAL FORMULAE
C    WITH THE REQUIRED ACCURACY
 4200 DO 4210 I=1,5                                                     JPW2298
      KZ(I+5)=0                                                         JPW2299
      NOCP=LP(ITWO)                                                     JPW2300
      CALL RELABS(I,NOCP)                                               JPW2301
      DO 4220 J=1,NP                                                    JPW2302
      IF(LP(J)-NOCP) 4220,4210,4220                                     JPW2303
 4220 CONTINUE                                                          JPW2304
 4210 KZ(I)=J                                                           JPW2305
      RDE(1)=-4.0                                                       JPW2306
      DO 4230 I=2,5                                                     JPW2307
      RDE(I)=1.0                                                        JPW2308
 4230 RDE(I+4)=0.0                                                      JPW2309
      GO TO 8080                                                        JPW2310
 3064 IY=LP(ITWO)/100                                                   JPW2311
      IX=LP(ITWO)-IY*100                                                JPW2312
      Y=IY                                                              JPW2313
      X=IX                                                              JPW2314
      Y=Y*H                                                             JPW2315
      X=X*H                                                             JPW2316
      X=X-XORIG                                                         JPW2317
      Y=Y-YORIG                                                         JPW2318
      Z1=Z(ITWO)                                                        JPW2319
      ZX=COE(4)*X*X*3.+2.*X*Y*COE(3)+Y*Y*COE(2)+2.*X*COE(7)+COE(6)      JPW2320
     1*Y+COE(9)                                                         JPW2321
      ZY=COE(3)*X*X+2.*COE(2)*Y*X+3.*COE(1)*Y*Y+COE(6)*X+2.*COE(5)      JPW2322
     1*Y+COE(8)                                                         JPW2323
      ZXX=COE(4)*6.*X+2.*COE(3)*Y+2.*COE(7)                             JPW2324
      ZXY=2.*COE(3)*X+2.*COE(2)*Y+COE(6)                                JPW2325
      ZYY=2.*COE(2)*X+6.*COE(1)*Y+2.*COE(5)                             JPW2326
      IF(COE1-.9)3051,3063,3063                                         JPW2327
 3051 Z1=Z(ITWO)**2                                                     JPW2328
      ZXX=(SQRTF(Z1)*.5*ZXX-.25*ZX*ZX/SQRTF(Z1))/Z1                     JPW2329
      ZXY=(SQRTF(Z1)*.5*ZXY-.25*ZY*ZX/SQRTF(Z1))/Z1                     JPW2330
      ZYY=(SQRTF(Z1)*.5*ZYY-.25*ZY*ZY/SQRTF(Z1))/Z1                     JPW2331
      ZX=ZX*.5/SQRTF(Z1)                                                JPW2332
      ZY=ZY*.5/SQRTF(Z1)                                                JPW2333
 3063 DO 3630 M=1,9                                                     JPW2334
      NOCP=LP(ITWO)                                                     JPW2335
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      CALL RELABS (M,NOCP)                                              JPW2336
      DO 3620 I=1,NP                                                    JPW2337
      IF(LP(I)-NOCP)3620,3630,3620                                      JPW2338
 3620 CONTINUE                                                          JPW2339
 3630 KZ(M)=I                                                           JPW2340
      GO TO (3001,3066,3001),INTSW                                      JPW2341
 3001 II=KZ(2)                                                          JPW2342
      IJ=KZ(3)                                                          JPW2343
      IK=KZ(4)                                                          JPW2344
      IL=KZ(5)                                                          JPW2345
      ZXX=(Z(II)+Z(IJ)-2.*Z(ITWO))/H**2                                 JPW2346
      ZYY=(Z(IK)+Z(IL)-2.*Z(ITWO))/H**2                                 JPW2347
      ZY       =(Z(IK)-Z(IL))/2.*H                                      JPW2348
      ZX       =(Z(II)-Z(IJ))/2.*H                                      JPW2349
      II=KZ(6)                                                          JPW2350
      IJ=KZ(7)                                                          JPW2351
      IK=KZ(8)                                                          JPW2352
      IL=KZ(9)                                                          JPW2353
      ZXY=(Z(II)+Z(IJ)-Z(IK)-Z(IL))/(4.*H**2)                           JPW2354
 3066 RDE(1)=(-2.*ZYY-2.*ZXX)/H**2                                      JPW2355
      RDE(2)=+ZYY/H**2                                                  JPW2356
      RDE(3)=+ZYY/H**2                                                  JPW2357
      RDE(4)= ZXX/H**2                                                  JPW2358
      RDE(5)= ZXX/H**2                                                  JPW2359
      RDE(6)=ZXY/(4.*H**2)                                              JPW2360
      RDE(7)=ZXY/(4.*H**2)                                              JPW2361
      RDE(8)=-ZXY/(4.*H**2)                                             JPW2362
      RDE(9)=-ZXY/(4.*H**2)                                             JPW2363
      IF(IPRINT) 8080,9005,8080                                         JPW2364
 9005 PRINT 1001,LP(ITWO),(RDE(I),I=1,9)                                JPW2365
      DO 1000 I=1,9                                                     JPW2366
      J=KZ(I)                                                           JPW2367
 1000 KZ1(I)=LP(J)                                                      JPW2368
      PRINT 1002,(KZ1(I),I=1,9)                                         JPW2369
 8080 DO 8090 M=1,9                                                     JPW2370
      JROW=M                                                            JPW2371
      I=KZ(M)                                                           JPW2372
 8110 IF(I-(MAT-1)*MDIM) 8120,8120,8130                                 JPW2373
 8120 J=I-(MAT-2)*MDIM                                                  JPW2374
      A1(MROW,J)=RDE(JROW)                                              JPW2375
      GO TO 8090                                                        JPW2376
 8130 IF(I-(MAT)*MDIM) 8140,8140,8150                                   JPW2377
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```
8140 J=I-(MAT-1)*MDIM                                                   JPW2378
     A2(MROW,J)=RDF(JROW)                                               JPW2379
     GO TO 8090                                                         JPW2380
8150 J=I-(MAT)*MDIM                                                     JPW2381
     A1(MROW,J)=RDF(JROW)                                               JPW2382
8090 CONTINUE                                                           JPW2383
8170 CONTINUE                                                           JPW2384
     GO TO 5007                                                         JPW2385
8210 MBIG=NOM*MDIM                                                      JPW2386
     NP1=NP+1                                                           JPW2387
     DO 8211 I=NP1,MBIG                                                 JPW2388
     K=I-MDIM*(NOM-1)                                                   JPW2389
8211 A2(K,K)=1.0                                                        JPW2390
     DO 8071 I=IROW,MBIG                                                JPW2391
     DO 8071 K=1,NL                                                     JPW2392
8071 Q(I,K)=0.0                                                         JPW2393
5007 CONTINUE                                                           JPW2394
8175 WRITE TAPE 12, ((A2(I,J),J=1,MDIM),I=1,MDIM)                       JPW2395
     DO 8176 I=1,MDIM                                                   JPW2396
     DO 8176 J=1,MDIM                                                   JPW2397
8176 A2(I,J)=0.0                                                        JPW2398
     DO 8177 I=1,MDIM                                                   JPW2399
     J=I                                                                JPW2400
     DO 8177 K=1,J                                                      JPW2401
     A2(I,K)=A1(I,K)                                                    JPW2402
8177 A1(I,K)=0.0                                                        JPW2403
     WRITE TAPE 10, ((A1(I,J),J=1,MDIM),I=1,MDIM)                       JPW2404
8200 WRITE TAPE 10, ((A2(I,J),J=1,MDIM),I=1,MDIM)                       JPW2405
     REWIND 10                                                          JPW2406
     REWIND 12                                                          JPW2407
     DO 8300 I=1,561                                                    JPW2408
     Q(I,3)=0.0                                                         JPW2409
8300 Q(I,2)=Q(I,1)                                                      JPW2410
     CALL CHAIN (1,B2)                                                  JPW2417
1001 FORMAT (// 10X,14HINTERNAL POINT,I6,/9F10.4)                       JPW2418
1002 FORMAT      (9I10//)                                               JPW2419
3451 FORMAT ( //5X,29HMOLECULES,AFTER JUDY,AT POINT I6/ )               JPW2420
3453 FORMAT  ( 10F12.3 )                                                JPW2421
3457 FORMAT(/I11,9I12)                                                  JPW2422
7015 FORMAT (//10X,4HZXX=F12.4,2X,4HZXY=,F12.4,2X,4HZYY=,F12.4,2X,3HZX= JPW2423
    1,F12.4,2X,3HZY=,F12.4/)                                            JPW2424
     END                                                                JPW2425
```

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*     CHAIN (1,B2)
*     LABEL                                                             JPW2919
CPART3                                                                  JPW2920
C   PHASE 3   SOLUTION OF THE SYSTEM OF DIFFERENCE EQUATIONS
C   SUBROUTINE SOLVER SOLVES A SET OF SIMULTANEOUS EQUATIONS WITH STRONG BAND
C   CHARACTER.   THE MAXIMUM DIMENSION OF THE MATRIX TO BE SOLVED IS 1000
C   SUBROUTINE SOLVER RETURNS A VECTOR SOL (1000,NL) WHERE NL IS THE MAXIMUM
C   NUMBER OF LOADING CONDITIONS.   TWO TAPES ARE USED DURING EXECUTION
      DIMENSION COE(10),TITLE(12),MCONS(3,100),MC(100),CPC(100,3),      JPW2921
     1LBP(500),LBPS(500),XBP(500),YBP(500),ZBP(500),COSS(100),SINS(100), JPW2922
     2LP(561),LPC(561),Z(561),Q(561,3)                                  JPW2923
      COMMON COE,TITLE,MCONS,MC,CPC,LBP,LBPS,XBP,YBP,ZBP,COSS,SINS,LP,LP JPW2924
     1C,Z,Q,INTSW,IEXQ,INEXT,NS,NC,NP,NL ,IMID,MDIM,H,COE1,XORIG,YORIG  JPW2925
      COMMON AN,LX,IPRINT                                               JPW2926
      DIMENSION R(60,1)                                                 JPW2927
D     DIMENSION A2(60,60)                                               JPW2928
      DIMENSION A1(60,60),A3(60,60)                                     JPW2929
      READ TAPE 10, ((A1(I,J),J=1,MDIM),I=1,MDIM)                       JPW2930
      READ TAPE 12, ((A2(I,J),J=1,MDIM),I=1,MDIM)                       JPW2931
      READ TAPE 10, ((A3(I,J),J=1,MDIM),I=1,MDIM)                       JPW2932
      IF(NP-MDIM) 40,40,50                                              JPW2933
   50 READ TAPE 10, ((A1(I,J),J=1,MDIM),I=1,MDIM)                       JPW2934
 40   NOM=NP/MDIM+1                                                     JPW2935
      NOM2=NOM-1                                                        JPW2936
      DO 8320 MAT=1,NOM                                                 JPW2937
D     CALL INVERT (A2,MDIM,IEXQ)                                        JPW2938
      DO 8260 I=1,MDIM                                                  JPW2939
      J=(MAT-1)*MDIM+I                                                  JPW2940
      DO 8260 K=1,NL                                                    JPW2941
 8260 R(I,K)=Q(J,K)                                                     JPW2942
      CALL MATMPL(A2,R,MDIM,MDIM,NL,2)                                  JPW2943
      DO 8261 I=1,MDIM                                                  JPW2944
      J=(MAT-1)*MDIM+I                                                  JPW2945
      DO 8261 K=1,NL                                                    JPW2946
 8261 Q(J,K)=R(I,K)                                                     JPW2947
      IF (MAT-NOM ) 60,70,60                                            JPW2948
   60 IF(NP-MDIM) 90,90,65                                              JPW2949
   65 CALL MATMPL (A2,A3,MDIM,MDIM,MDIM,2)                              JPW2950
      WRITE TAPE 11, ((A3(I,J),J=1,MDIM),I=1,MDIM)                      JPW2951
      CALL MATMPL (A1,A3,MDIM,MDIM,MDIM,2)                              JPW2952
      READ TAPE 12, ((A2(I,J),J=1,MDIM),I=1,MDIM)                       JPW2953
      DO 8280 I=1,MDIM                                                  JPW2954
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      DO 8280 J=1,MDIM                                                  JPW2955
 8280 A2(I,J)=A3(I,J)-A2(I,J)                                           JPW2956
      CALL MATMPL (A1,R,MDIM,MDIM,NL,2)                                 JPW2957
      DO 8300 I=1,MDIM                                                  JPW2958
      J1=MAT*MDIM+I                                                     JPW2959
      DO 8300 K=1,NL                                                    JPW2960
 8300 Q(J1,K)=R(I,K)-Q(J1,K)                                            JPW2961
      IF(MAT-NOM2) 75,8320,8320                                         JPW2962
   75 READ TAPE 10, ((A3(I,J),J=1,MDIM),I=1,MDIM)                       JPW2963
      DO 8282 I=1,MDIM                                                  JPW2964
      DO 8282 J=1,MDIM                                                  JPW2965
 8282 A3(I,J)=-A3(I,J)                                                  JPW2966
      READ TAPE 10, ((A1(I,J),J=1,MDIM),I=1,MDIM)                       JPW2967
 8320 CONTINUE                                                          JPW2968
   70 DO 8380 MAT=2,NOM                                                 JPW2969
      BACKSPACE 11                                                      JPW2970
      IMAT=NOM-MAT+1                                                    JPW2971
      DO 8340 I=1,MDIM                                                  JPW2972
      J=IMAT*MDIM+I                                                     JPW2973
      DO 8340 K=1,NL                                                    JPW2974
 8340 R(I,K)=Q(J,K)                                                     JPW2975
      READ TAPE 11, ((A1(I,J),J=1,MDIM),I=1,MDIM)                       JPW2976
      CALL MATMPL (A1,R,MDIM,MDIM,NL,2)                                 JPW2977
      DO 8360 I=1,MDIM                                                  JPW2978
      J=(IMAT-1)*MDIM+I                                                 JPW2979
      DO 8360 K=1,NL                                                    JPW2980
 8360 Q(J,K)=Q(J,K)-R(I,K)                                              JPW2981
      BACKSPACE 11                                                      JPW2982
 8380 CONTINUE                                                          JPW2983
   90 REWIND 10                                                         JPW2984
      REWIND 12                                                         JPW2985
      CALL CHAIN (1,B3)                                                 JPW2986
      END                                                               JPW2987
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*     CHAIN (1,B3)
*     LABEL
CPART4                                                                  JPW3092
C   PART FOUR BACK-SUBSTITUTES THE SOLUTION INTO THE ORIGINAL DIFFERENCE FOUS.
C        AS A GUIDE TO COMPUTATIONAL ERRORS
      DIMENSION COE(10),TITLE(12),MCONS(3,100),MC(100),CPC(100,3),      JPW3094
     1LBP(500),LBPS(500),XBP(500),YBP(500),ZBP(500),COSS(100),SINS(100), JPW3095
     2LP(561),LPC(561),Z(561),Q(561,3)                                  JPW3096
      COMMON COE,TITLE,MCONS,MC,CPC,LBP,LBPS,XBP,YBP,ZBP,COSS,SINS,LF,LP JPW3097
     1C,Z,Q,INTSW,IEXQ,INEXT,NS,NC,NP,NL  ,IMID,MDIM,H,COE1,XORIG,YORIG  JPW3098
      COMMON AN,LX,IPRINT                                               JPW3099
      DIMENSION A(61,183),QS(183)                                       JPW3100
      REWIND 10                                                         JPW3101
      REWIND 12                                                         JPW3102
      IF(IPRINT)101,102,101                                             JPW3103
  102 PRINT 3                                                           JPW3104
      PRINT2,LX                                                         JPW3105
  101 ILOOP=0                                                           JPW3106
      NOM=NP/MDIM+1                                                     JPW3107
      MDIM1=MDIM+1                                                      JPW3108
      MDIM2=MDIM*2+1                                                    JPW3109
      MDIM3=MDIM*3                                                      JPW3110
      MDIM4=MDIM*2                                                      JPW3111
      MOP=NOM*MDIM                                                      JPW3112
      NP1=NP+1                                                          JPW3113
      DO 4 I=NP1,MOP                                                    JPW3114
    4 LP(I)=0                                                           JPW3115
      DO 5 I=1,MOP                                                      JPW3116
      Q(I,3)=Q(I,3)+Q(I,1)                                              JPW3117
    5 Q(I,1)=Q(I,3)                                                     JPW3118
      DO 50 KBACK=1,NOM                                                 JPW3119
      READ TAPE 10, ((A(I,J),J=1     ,MDIM ),I=1,MDIM)                  JPW3120
      READ TAPE 12, ((A(I,J),J=MDIM1,MDIM4),I=1,MDIM)                   JPW3121
      READ TAPE 10, ((A(I,J),J=MDIM2,MDIM3),I=1,MDIM)                   JPW3122
      IF (NOM-2) 10,20,30                                               JPW3123
   10 DO 15 I=1,MDIM                                                    JPW3124
      J=MDIM+I                                                          JPW3125
   15 QS(J)=Q(I,3)                                                      JPW3126
      DO 16 I=1,MDIM                                                    JPW3127
      QS(I)=0.0                                                         JPW3128
      J=MDIM*2+I                                                        JPW3129
   16 QS(J)=0.0                                                         JPW3130
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      CALL MATMPL (A,QS,MDIM,MDIM3,1,1)                                 JPW3131
      GO TO 44                                                          JPW3132
   20 DO 21 I=1,MDIM4                                                   JPW3133
      IF(KBACK-1) 22,22,23                                              JPW3134
   22 J=MDIM+I                                                          JPW3135
      GO TO 21                                                          JPW3136
   23 J=I                                                               JPW3137
   21 QS(J)=Q(I,3)                                                      JPW3138
      DO 26 I=1,MDIM                                                    JPW3139
      IF(KBACK-1) 27,27,28                                              JPW3140
   27 J=I                                                               JPW3141
      GO TO 26                                                          JPW3142
   28 J=MDIM*2+I                                                        JPW3143
   26 QS(J)=0.0                                                         JPW3144
      CALL MATMPL (A,QS,MDIM,MDIM3,1,1)                                 JPW3145
      GO TO 44                                                          JPW3146
   30 DO 31 I=1,MDIM3                                                   JPW3147
      IF(KBACK-1) 32,32,33                                              JPW3148
   32 J=MDIM+I                                                          JPW3149
      IF(J-MDIM3) 36,36,31                                              JPW3150
   36 QS(J)=Q(I,3)                                                      JPW3151
      GO TO 31                                                          JPW3152
   33 K=(KBACK-2)*MDIM+I                                                JPW3153
      IF(K-NP) 35,35,100                                                JPW3154
  100 QS(I)=0.0                                                         JPW3155
      GO TO 31                                                          JPW3156
   35 QS(I)=Q(K,3)                                                      JPW3157
   31 CONTINUE                                                          JPW3158
      IF(KBACK-1) 37,37,39                                              JPW3159
   37 DO 41 I=1,MDIM                                                    JPW3160
   41 QS(I)=0.0                                                         JPW3161
   39 CALL MATMPL (A,QS,MDIM,MDIM3,1,1)                                 JPW3162
   44 DO 45 I=1,MDIM                                                    JPW3163
      J=(KBACK-1)*MDIM+I                                                JPW3164
      Q(J,1)=Q(J,2)-A(I,1)                                              JPW3165
      IF(IPRINT) 104,103,104                                            JPW3166
  103 PRINT 1,LP(J),Q(J,2),Q(J,1),Q(J,3)                                JPW3167
  104 IF (ABSF(Q(J,1))-ABSF(Q(J,2)/1000.)) 45,45,47                     JPW3168
   47 IF (ABSF(Q(J,2)) -.001) 45,45,61                                  JPW3169
   61 ILOOP=ILOOP+1                                                     JPW3170
   45 CONTINUE                                                          JPW3171
   50 CONTINUE                                                          JPW3172
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      IF(IPRINT) 111,110,111                                            JPW3179
110   PRINT 3                                                           JPW3180
 111  REWIND 10                                                         JPW3181
      REWIND 12                                                         JPW3182
      LX=LX+1                                                           JPW3183
      IF(LX-1)53,51,53                                                  JPW3184
   53 IF(LX-50) 55,55,54                                                JPW3185
   54 PRINT 56,ILOOP                                                    JPW3186
      GO TO 52                                                          JPW3187
   56 FORMAT (10X,94HTHE SOLUTION TO THE SYSTEM OF DIFFERENCE EQUATIONS JPW3188
     1MAY CONTAIN SIGNIFICANT ROUNDOFF ERRORS FOR,I3,8H POINTS,///)     JPW3189
   55 IF(ILOOP-1) 52,52,51                                              JPW3190
   51 CALL CHAIN (1,B2)                                                 JPW3191
   52 CALL CHAIN (3,B1)                                                 JPW3192
    1 FORMAT (10X,I4,3F20.6)                                            JPW3193
    2 FORMAT (15X,28HSOLUTION FOR STRESS FUNCTION//10X,12HAT ITERATION,I JPW3194
     14,//12X,2HAT11X,9HEFFECTIVE,11X,9HROUND-OFF,12X,7HCURRENT/10X5HPOI JPW3195
     2NT,12X,4HLOAD,16X,5HERROR,13X,9HSOLUTIONS/)                       JPW3196
    3 FORMAT (1H1)                                                      JPW3197
      END                                                               JPW3198
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*     CHAIN (3,B1)
*     LIST8                                                            JPW3222
*     LABEL                                                            JPW3223
CPART5                                                                 JPW3224
C   PHASE 5 CALCULATES THE  VALUES OF THE SECOND DERIVATIVE OF F WITH RESPECT
C   TO X,Y, AND X AND Y FOR LATER USE IN DETERMINING THE REACTIONS OF THE BOUN-
C   DARY.  ZX AND ZY ARE ALSO CALCULATED
      DIMENSION COE(10),TITLE(12),MCONS(3,100),MC(100),CPC(100,3),       JPW3225
     1LBP(500),LBPS(500),XBP(500),YBP(500),ZBP(500),COSS(100),SINS(100), JPW3226
     2LP(561),LPC(561),Z(561),Q(561,3)                                  JPW3227
      COMMON COE,TITLE,MCONS,MC,CPC,LBP,LBPS,XBP,YBP,ZBP,COSS,SINS,LP,LP JPW3228
     1C,Z,Q,INTSW,IEXQ,INEXT,NS,NC,NP,NL ,IMID,MDIM,H,COE1,XORIG,YORIG  JPW3229
      COMMON AN,LX,IPRINT                                               JPW3230
      DIMENSION AZ(10,21),ZBC(6),KZBC(16),IA(12),T(10),L(12),RFXXBC(10), JPW3231
     1RFXYBC(10),RFYYBC(10)                                             JPW3232
      REWIND 12                                                         JPW3233
C   MATRICES AZ AND AF ARE CLEARED
      DO 4000 ITWO=1,IMID                                               JPW3234
      DO 4010 I=1,10                                                    JPW3235
      DO 4030 J=1,21                                                    JPW3236
 4030 AZ(I,J)=0.0                                                       JPW3237
      RFXXBC(I)=0.0                                                     JPW3238
      RFXYBC(I)=0.0                                                     JPW3239
 4010 RFYYBC(I)=0.0                                                     JPW3240
      DO 4011 I=1,16                                                    JPW3241
 4011 KZBC(I)=0                                                         JPW3242
      K=1                                                               JPW3243
C   THE COORDINATES OF THE NEAREST INTERIOR POINT TO POINT XBP,YBP ARE CALCULA-
C   TED.   THE LIST OF INTERIOR POINTS IS NOW SEARCHED FOR THIS POINT
      PX=XBP(ITWO)/H                                                    JPW3244
      PY=YBP(ITWO)/H                                                    JPW3245
      IX=PX                                                             JPW3246
      IY=PY                                                             JPW3247
      L(1)=IY*100+IX                                                    JPW3248
      L(2)=L(1)+100                                                     JPW3249
      L(3)=L(1)+101                                                     JPW3250
      L(4)=L(1)+1                                                       JPW3251
      DO 4040 J=5,12                                                    JPW3252
 4040 L(J)=0                                                            JPW3253
 4050 DO 4060 ILBP=1,12                                                 JPW3254
      IA(ILBP)=0                                                        JPW3255
      DO 4070 JLBP=1,NP                                                 JPW3256
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      IF(L(ILBP)-LP(JLBP))4070,4080,4070                                JPW3257
 4070 CONTINUE                                                          JPW3258
      GO TO 4060                                                        JPW3259
 4080 IA(ILBP)=JLBP                                                     JPW3260
 4060 CONTINUE                                                          JPW3261
      DO 4090 II=1,12                                                   JPW3262
      IF(IA(II))4090,4090,4100                                          JPW3263
 4090 CONTINUE                                                          JPW3264
C   IF THIS INTERIOR POINT IS NOT FOUND IN LP,  OTHER NEARBY INTERIOR POINTS
C   ARE CALCULATED IN THE FORM OF ABSOLUTE NUMBERS AND SEARCHED FOR IN LP.
      L(1)=L(1)-1                                                       JPW3265
      L(2)=L(2)-1                                                       JPW3266
      L(3)=L(3)+1                                                       JPW3267
      L(4)=L(4)+1                                                       JPW3268
      L(5)=L(1)-99                                                      JPW3269
      L(6)=L(2)+101                                                     JPW3270
      L(7)=L(3)+99                                                      JPW3271
      L(8)=L(4)-101                                                     JPW3272
      L(9)=L(1)-100                                                     JPW3273
      L(10)=L(2)+100                                                    JPW3274
      L(11)=L(3)+100                                                    JPW3275
      L(12)=L(4)-100                                                    JPW3276
      GO TO 4050                                                        JPW3277
 4100 DMIN=1000.*H                                                      JPW3278
C   WHEN ONE OR MORE OF THESE INTERIOR POINTS ARE FOUND IN LP THE CLOSEST ONE TO
C   THE BOUNDARY POINT IN QUESTION IS SELECTED
      DO 4120 IJ=1,12                                                   JPW3279
      IF(IA(IJ))4120,4120,4130                                          JPW3280
 4130 I=IA(IJ)                                                          JPW3281
      IY=LP(I)/100                                                      JPW3282
      IX=LP(I)-IY*100                                                   JPW3283
      Y=IY                                                              JPW3284
      X=IX                                                              JPW3285
      D=SQRTF(((X*H)-XBP(ITWO))**2+((Y*H)-YBP(ITWO))**2)                JPW3286
      IF(D-DMIN)4140,4120,4120                                          JPW3287
 4140 DMIN=D                                                            JPW3288
      YMIN=Y*H                                                          JPW3289
      XMIN=X*H                                                          JPW3290
      IMIN=IJ                                                           JPW3291
 4120 CONTINUE                                                          JPW3292
      I=IA(IMIN)                                                        JPW3293
      IF(IPRINT) 9001,9000,9001                                         JPW3294
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9000 PRINT 5000,LP(I),ITWO                                          JPW3295
9001 IBEEN=0                                                        JPW3296
3080 IFIVE=ITWO                                                     JPW3297
3079 D=0.0                                                          JPW3298
     XD=XBP(ITWO)                                                   JPW3299
     YD=YBP(ITWO)                                                   JPW3300
     DO 3081 I=1,NS                                                 JPW3301
     IF(MCONS(1,I)-LBPS(IFIVE)) 3081,3082,3081                      JPW3302
3081 CONTINUE                                                       JPW3303
     STOP                                                           JPW3304
3082 DO 3083 J=1,NS                                                 JPW3305
     IF(MC(J)-MCONS(2,I)) 3083,3085,3083                            JPW3306
3083 CONTINUE                                                       JPW3307
     STOP                                                           JPW3308
3085 X1=CPC(J,1)                                                    JPW3309
     Y1=CPC(J,2)                                                    JPW3310
     DO 3084 J=1,NS                                                 JPW3311
     IF(MC(J)-MCONS(3,I))3084,3086,3084                             JPW3312
3084 CONTINUE                                                       JPW3313
     STOP                                                           JPW3314
3086 X2=CPC(J,1)                                                    JPW3315
     Y2=CPC(J,2)                                                    JPW3316
     X3=XBP(ITWO)                                                   JPW3317
     Y3=YBP(ITWO)                                                   JPW3318
     IIN=0                                                          JPW3319
     JSIDE=I                                                        JPW3320
3100 KD=1                                                           JPW3321
3110 IF(KD-2) 3230,3130,3140                                        JPW3322
3130 XD=XD+H*COSS(JSIDE)                                            JPW3323
     YD=YD+SINS(JSIDE)*H                                            JPW3324
     GO TO 3120                                                     JPW3325
3140 IF(IIN)3141,3141,3142                                          JPW3326
3142 XD=XD+1.5*COSS(JSIDE)*H                                        JPW3327
     YD=YD+1.5*SINS(JSIDE)*H                                        JPW3328
3141 XD=XD-H*COSS(JSIDE)*2.0                                        JPW3329
     YD=YD-H*SINS(JSIDE)*2.0                                        JPW3330
3120 IF(IIN-3) 3121,3090,3090                                       JPW3331
3121 IF(ABSF(SINS(JSIDE))-.707) 3180,3180,3190                      JPW3332
3180 IF(XD-X1)3200,3210,3210                                        JPW3333
3200 IF(XD-X2)3220,3230,3230                                        JPW3334
3210 IF(XD-X2)3230,3220,3220                                        JPW3335
3190 IF(YD-Y1)3240,3250,3250                                        JPW3336
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3240 IF(YD-Y2)3220,3230,3230                                          JPW3337
3250 IF(YD-Y2)3230,3220,3220                                          JPW3338
3220 IF(KD-2) 3221,3221,3222                                          JPW3339
3221 XD=XD-1.5*H*COSS(JSIDE)                                          JPW3340
     YD=YD-1.5*H*SINS(JSIDE)                                          JPW3341
     IIN=IIN+1                                                        JPW3342
     GO TO 3120                                                       JPW3343
3222 XD=XD+1.5*H*COSS(JSIDE)                                          JPW3344
     YD=YD+1.5*H*SINS(JSIDE)                                          JPW3345
     IIN=IIN+1                                                        JPW3346
     GO TO 3120                                                       JPW3347
3230 ALFA=(XD-X3)/H                                                   JPW3348
     BETA=(YD-Y3)/H                                                   JPW3349
     CALL TSF(ALFA,BETA,T)                                            JPW3350
3269 DO 3270 IT=1,10                                                  JPW3351
3270 AZ(IT,K)=T(IT)                                                   JPW3352
     KZBC(K)=K                                                        JPW3353
     CALL FINDZD(MCONS,LBPS,XBP,YBP,ZBP,SINS,XD,YD,IMID,JSIDE,ZD)     JPW3354
     ZBC(K)=ZD                                                        JPW3355
     K=K+1                                                            JPW3356
3260 KD=KD+1                                                          JPW3357
     IF(KD-3) 3110,3110,3090                                          JPW3358
3090 IBEEN=IBEEN+1                                                    JPW3359
     IF(IBEEN-1) 3091,3096,3091                                       JPW3360
3096 IF(ITWO-1) 3092,3094,3092                                        JPW3361
3092 IF(ITWO-IMID) 3093,3095,3093                                     JPW3362
3094 IFIVE=IMID                                                       JPW3363
     GO TO 3079                                                       JPW3364
3095 IFIVE=1                                                          JPW3365
     GO TO 3079                                                       JPW3366
3093 IF(LBPS(ITWO)-LBPS(ITWO+1)) 3088,3087,3088                       JPW3367
3087 IF(LBPS(ITWO)-LBPS(ITWO-1)) 3089,3091,3089                       JPW3368
3088 IFIVE=ITWO+1                                                     JPW3369
     GO TO 3079                                                       JPW3370
3089 IFIVE=ITWO-1                                                     JPW3371
     GO TO 3079                                                       JPW3372
3091 DO 4150 M=1,49                                                   JPW3373
     I=IA(IMIN)                                                       JPW3374
     NOCP=LP(I)                                                       JPW3375
     CALL RELABS (M,NOCP)                                             JPW3376
     DO 4160 J=1,NP                                                   JPW3377
     IF(LP(J)-NOCP)4160,4170,4160                                     JPW3378
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 4160 CONTINUE                                                          JPW3379
      GO TO 4150                                                        JPW3380
 4170 CALL ALBETA(M,ALFA,BETA)                                          JPW3381
      ALFA=ALFA+(XMIN-XBP(ITWO))/H                                      JPW3382
      BETA=BETA+(YMIN-YBP(ITWO))/H                                      JPW3383
      CALL TSF(ALFA,BETA,T)                                             JPW3384
      DO 4180 IT=1,10                                                   JPW3385
 4180 AZ(IT,K)=T(IT)                                                    JPW3386
      KZBC(K)=NOCP                                                      JPW3387
C   KZBC AND KFBC ARE VECTORS CONTAINING THE ABSOLUTE NUMBERS OF THE POINTS
C   REFERRED TO BY COLUMNS OF AZ AND AF
C   THESE VECTORS ARE USED  LATER IN THE SOLUTION OF AZ AND AF
      K=K+1
      IF(K-16) 4150,4150,4155                                           JPW3388
 4150 CONTINUE                                                          JPW3389
 4155 GO TO (4510,4520,4510),INTSW                                      JPW3390
 4520 X=XBP(ITWO)-XORIG                                                 JPW3391
      Y=YBP(ITWO)-YORIG                                                 JPW3392
      ZXBC=COE(4)*X*X*3.+2.*X*Y*COE(3)+Y*Y*COE(2)+2.*X*COE(7)+COE(6)    JPW3393
     1*Y+COE(9)                                                         JPW3394
      ZYBC=COE(3)*X*X+2.*COE(2)*Y*X+3.*COE(1)*Y*Y+COE(6)*X+2.*COE(5)    JPW3395
     1*Y+COE(8)                                                         JPW3396
      IF(COE1-.9) 4800,4800,4510                                        JPW3397
 4800 ZXBC=ZXBC*.5/ZBP(ITWO)                                            JPW3398
      ZYBC=ZYBC*.5/ZBP(ITWO)                                            JPW3399
 4510 AZ(4,17)=1.0                                                      JPW3400
      AZ(5,18)=1.0                                                      JPW3401
      AZ(6,19)=1.0                                                      JPW3402
      AZ(2,20)=1.0                                                      JPW3403
      AZ(3,21)=1.0                                                      JPW3404
      NBC=1                                                             JPW3405
      CALL JUDY(AZ,10,16,KZBC,NBC,LP,ITWO,IEXQ,5)                       JPW3406
      IF(IPRINT) 9051,9050,9051                                         JPW3407
 9050 PRINT 5002                                                        JPW3408
      PRINT 5005,(AZ(I,17),I=1,10)                                      JPW3409
      PRINT 5005,(AZ(I,18),I=1,10)                                      JPW3410
      PRINT 5005,(AZ(I,19),I=1,10)                                      JPW3411
      PRINT 5003,(KZBC(I),I=1,10)                                       JPW3412
 9051 DO 9052 I=1,10                                                    JPW3413
      DO 9053 J=17,19                                                   JPW3414
 9053 AZ(I,J)=AZ(I,J)/H**2                                              JPW3415
      DO 9052 J=20,21                                                   JPW3416
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9052 AZ(I,J)=AZ(I,J)/H                                                  JPW3418
     GO TO (4211,4211,4540),INTSW                                       JPW3419
4540 ZXBC=0.0                                                           JPW3420
     ZYBC=0.0                                                           JPW3421
     DO 4541 IZ=1,10                                                    JPW3422
     I=KZBC(IZ)                                                         JPW3423
     IF(KZBC(IZ)) 4542,4541,4542                                        JPW3424
4542 IF(KZBC(IZ)-6) 4543,4543,4544                                      JPW3425
4544 DO 4539 J=1,NP                                                     JPW3426
     IF(LP(J)-I) 4539,4538,4539                                         JPW3427
4539 CONTINUE                                                           JPW3428
     PRINT 4310,I                                                       JPW3429
     STOP                                                               JPW3430
4538 ZXBC=ZXBC+AZ(IZ,20)*Q(J,3)                                         JPW3431
     ZYBC=ZYBC+AZ(IZ,21)*Q(J,3)                                         JPW3432
     GO TO 4541                                                         JPW3433
4543 ZXBC=ZXBC+AZ(IZ,20)*ZBC(I)                                         JPW3434
     ZYBC=ZYBC+AZ(IZ,21)*ZBC(I)                                         JPW3435
4541 CONTINUE                                                           JPW3436
4570 WRITE TAPE 12,ZXBC,ZYBC                                            JPW3437
     GO TO 4000                                                         JPW3438
4211 DO 4630 IZ=1,10                                                    JPW3439
     REXXBC(IZ)=AZ(IZ,17)                                               JPW3440
     REXYBC(IZ)=AZ(IZ,18)                                               JPW3441
4630 REYYBC(IZ)=AZ(IZ,19)                                               JPW3442
     GO TO (4610,4650,4000),INTSW                                       JPW3443
4610 DO 4240 IZ=1,10                                                    JPW3444
     IF(KZBC(IZ)) 4240,4240,4239                                        JPW3445
4239 IF(KZBC(IZ)-6) 4250,4250,4260                                      JPW3446
4250 J=KZBC(IZ)                                                         JPW3447
     DO 4270 JZ=20,21                                                   JPW3448
     AZ(IZ,JZ)=AZ(IZ,JZ)*ZBC(J)                                         JPW3449
     IF(IZ-1)4280,4270,4280                                             JPW3450
4280 AZ(1,JZ)=AZ(1,JZ)+AZ(IZ,JZ)                                        JPW3451
4270 CONTINUE                                                           JPW3452
     GO TO 4240                                                         JPW3453
4260 DO 4290 ILP=1,NP                                                   JPW3454
     IF(LP(ILP)-KZBC(IZ))4290,4300,4290                                 JPW3455
4290 CONTINUE                                                           JPW3456
     PRINT 4310,KZBC(IZ)                                                JPW3457
4310 FORMAT(5X,I4,29H IS NOT IN THE LIST OF POINTS//)                   JPW3458
     CALL CHAIN(1,B1)                                                   JPW3459
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 4300 DO 4320 JZ=20,21                                                  JPW3460
      AZ(IZ,JZ)=AZ(IZ,JZ)*Z(ILP)                                        JPW3461
      IF(IZ-1)4330,4320,4330                                            JPW3462
 4330 AZ(1,JZ)=AZ(1,JZ)+AZ(IZ,JZ)                                       JPW3463
 4320 CONTINUE                                                          JPW3464
 4240 CONTINUE                                                          JPW3465
      ZXBC=AZ(1,20)                                                     JPW3466
      ZYBC=AZ(1,21)                                                     JPW3467
 4650 IF(IPRINT) 9010,9011,9010                                         JPW3468
 9011 PRINT 5004, ZXBC       ,ZYBC                                      JPW3469
C    RFXXBC IS THE SECOND DERIVATIVE OF F WITH RESPECT TO X AT THE BOUNDARY POINT
C    OF ADDRESS ITWO.    SIMILARLY RFXYBC AND RFYYBC REFER TO SECOND DERIVATIVES
C    WITH RESPECT TO X AND Y AND TO Y
 9010 WRITE TAPE 12, (KZBC(I),RFXXBC(I),RFXYBC(I),RFYYBC(I),I=1,10 ),ZXB JPW3470
     1C,ZYBC                                                            JPW3471
 4000 CONTINUE                                                          JPW3472
C    END OF PHASE 5
      CALL CHAIN (4,B1)                                                 JPW3479
 5000 FORMAT(//10X,I4,25H IS CLOSECT GRID POINT TO,I4,18H TH BOUNDARY PO JPW3480
     1INT/ )                                                            JPW3481
 5002 FORMAT(/5X,30HMOLECULES FOR F,XX  F,XY  F,YY,/)                   JPW3482
 5003 FORMAT(/ 10X,12HUSING POINTS,10I10/)                              JPW3483
 5004 FORMAT ( 15X,4HZ,X=F8.3,3X,4HZ,Y=F8.3/)                           JPW3484
 5005 FORMAT (22X,10F10.3)                                              JPW3485
      END                                                               JPW3486
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*     CHAIN (4,B1)
*     LIST8                                                             JPW3863
*     LABEL                                                             JPW3864
CPART6                                                                  JPW3865
C  PART 6 CALCULATES AND OUTPUTS THE FINAL STRESS RESULTANTS
      DIMENSION COE(10),TITLE(12),MCONS(3,100),MC(100),CPC(100,3),      JPW3866
     1LBP(500),LBPS(500),XBP(500),YBP(500),ZBP(500),COSS(100),SINS(100), JPW3867
     2LP(561),LPC(561),Z(561),Q(561,3)                                  JPW3868
      COMMON COE,TITLE,MCONS,MC,CPC,LBP,LBPS,XBP,YBP,ZBP,COSS,SINS,LP,LP JPW3869
     1C,Z,Q,INTSW,IEXQ,INEXT,NS,NC,NP,NL ,IMID,MDIM,H,COE1,XORIG,YORIG  JPW3870
      COMMON AN,LX,IPRINT                                               JPW3871
      DIMENSION RFXX(15),RFXY(15),RFYY(15),KF(15),RFXXBC(10),RFXYBC(10) JPW3872
      DIMENSION RFYYBC(10),KFBC(10),RDF(15), KT(9),KA(9),A(10),K(10)    JPW3873
      REWIND 11                                                         JPW3875
      REWIND 12                                                         JPW3876
      DO 4001 I=1,NP                                                    JPW3877
 4001 Q(I,1)=Q(I,3)                                                     JPW3878
      DO 6005 LOAD=1,NL                                                 JPW3879
      PUNCH 9000                                                        JPW3880
      PRINT 6002                                                        JPW3881
      PRINT 6000                                                        JPW3882
      PRINT 6001,LOAD                                                   JPW3883
      ICOUNT=0                                                          JPW3884
C   THE PROJECTED STRESS RESULTANTS ON THE X Y PLANE ARE CALCULATED
      DO 6010 ITWO=1,NP                                                 JPW3885
      GO TO (4000,4000,4010),INTSW                                      JPW3886
 4010 IF(LPC(ITWO)-1) 4015,4100,4015                                    JPW3887
 4015 FXX=AN                                                            JPW3888
      FYY=AN                                                            JPW3889
      FXY=0.0                                                           JPW3890
      ZX=0.0                                                            JPW3891
      ZY=0.0                                                            JPW3892
      READ TAPE 11, (KF(I),RFXX(I),RFYY(I),I=1,10)                      JPW3893
      DO 4020 I=1,10                                                    JPW3894
      IF(KF(I)-6) 4020,4020,4030                                        JPW3895
 4030 DO 4040 J=1,NP                                                    JPW3896
      IF(KF(I)-LP(J)) 4040,4050,4040                                    JPW3897
 4040 CONTINUE                                                          JPW3898
 4050 ZX=ZX+Q(J,1)*RFXX(I)                                              JPW3899
      ZY=ZY+Q(J,1)*RFYY(I)                                              JPW3900
 4020 CONTINUE                                                          JPW3901
      IF(KF(1)-6)4060,4060,4070                                         JPW3902
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 4060 ZX=ZX+RFXX(1)                                                     JPW3903
      ZY=ZY+RFYY(1)                                                     JPW3904
 4070 Z(ITWO)=Q(ITWO,1)                                                 JPW3905
      GO TO 6120                                                        JPW3906
 4100 DO 4130 I=1,5                                                     JPW3907
      NOCP=LP(ITWO)                                                     JPW3908
      CALL RFLABS(I,NOCP)                                               JPW3909
      DO 4120 J=1,NP                                                    JPW3910
      IF(LP(J)-NOCP) 4120,4130,4120                                     JPW3911
 4120 CONTINUE                                                          JPW3912
 4130 KA(I)=J                                                           JPW3913
      II=KA(2)                                                          JPW3914
      IJ=KA(3)                                                          JPW3915
      IK=KA(4)                                                          JPW3916
      IL=KA(5)                                                          JPW3917
      Z(ITWO)=Q(ITWO,1)                                                 JPW3918
      ZX=(Q(II,1)-Q(IJ,1))/(2.*H)                                       JPW3919
      ZY=(Q(IK,1)-Q(IL,1))/(2.*H)                                       JPW3920
C   FYY IS THE SECOND DERIVATIVE OF F WITH RESPECT TO X
C   FXX IS THE SECOND DERIVATIVE OF F WITH RESPECT TO Y
      FXX=AN                                                            JPW3921
      FYY=AN                                                            JPW3922
      FXY=0.0                                                           JPW3923
      GO TO 6120                                                        JPW3924
 4000 FXX=0.0                                                           JPW3925
      FXY=0.0                                                           JPW3926
      FYY=0.0                                                           JPW3927
      IF(LPC(ITWO)-1) 6020,6030,6020                                    JPW3928
 6020 ICOUNT=ICOUNT+1                                                   JPW3929
      READ TAPE 11, (KF(I),RFXX(I),RFXY(I),RFYY(I),I=1,10),ZX,ZY        JPW3930
      DO 6040 I=1,10                                                    JPW3931
      IF(KF(I)-6) 6040,6040,6050                                        JPW3932
 6050 DO 6060 J=1,NP                                                    JPW3933
      IF(LP(J)-KF(I))6060,6070,6060                                     JPW3934
 6060 CONTINUE                                                          JPW3935
 6070 FXX=FXX+  Q(J,LOAD)*RFXX(I)                                       JPW3936
      FXY=FXY+  Q(J,LOAD)*RFXY(I)                                       JPW3937
      FYY=FYY+  Q(J,LOAD)*RFYY(I)                                       JPW3938
 6040 CONTINUE                                                          JPW3939
      GO TO 6120                                                        JPW3940
 6030 DO 6080 I=2,9                                                     JPW3941
      NOCP=LP(ITWO)                                                     JPW3942
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      CALL RELABS(I,NOCP)                                               JPW3943
 6080 KT(I)=NOCP                                                        JPW3944
      KT(1)=LP(ITWO)                                                    JPW3945
      DO 6090 I=2,9                                                     JPW3946
      DO 6100 J=1,NP                                                    JPW3947
      IF(LP(J)-KT(I))6100,6090,6100                                     JPW3948
 6100 CONTINUE                                                          JPW3949
 6090 KA(I)=J                                                           JPW3950
      II=KA(6)                                                          JPW3951
      IJ=KA(7)                                                          JPW3952
      IK=KA(8)                                                          JPW3953
      IL=KA(9)                                                          JPW3954
C   FXY IS THE SECOND DERIVATIVE OF F WITH RESPECT TO X AND Y
      FXY=(  Q(II,LOAD)+  Q(IJ,LOAD)-  Q(IK,LOAD)-  Q(IL,LOAD))/(4.*H*H) JPW3955
      KA(1)=ITWO                                                        JPW3956
      II=KA(2)                                                          JPW3957
      IJ=KA(3)                                                          JPW3958
      IK=KA(4)                                                          JPW3959
      IL=KA(5)                                                          JPW3960
C   FXX IS AT THIS POINT THE SECOND DERIVATIVE OF THE STRESS FUNCTION F WITH
C   RESPECT TO X
      FXX=(  Q(II,LOAD)+  Q(IJ,LOAD)-2.*  Q(ITWO,LOAD))/H**2            JPW3961
C   FYY IS THE SECOND DERIVATIVE OF F WITH RESPECT TO Y
      FYY=(  Q(IK,LOAD)+  Q(IL,LOAD)-2.*  Q(ITWO,LOAD))/H**2            JPW3962
      GO TO (3099,3098,3099),INTSW                                      JPW3963
 3098 IY=LP(ITWO)/100                                                   JPW3964
      IX=LP(ITWO)-IY*100                                                JPW3965
      Y=IY                                                              JPW3966
      X=IX                                                              JPW3967
      Y=Y*H                                                             JPW3968
      X=X*H                                                             JPW3969
      X=X-XORIG                                                         JPW3970
      Y=Y-YORIG                                                         JPW3971
      Z1=Z(ITWO)                                                        JPW3972
      ZX=COE(2)*Y*Y+COE(3)*2.*X*Y+COE(4)*3.*X*X+COE(6)*Y+COE(7)*2.*X+COE JPW3973
     1(9)                                                               JPW3974
      ZY=3.*COE(1)*Y*Y+2.*COE(2)*Y*X+COE(3)*X*X+2.*COE(5)*Y+COE(6)*X+COE JPW3975
     1(8)                                                               JPW3976
      IF(COF1-.9)3097,6120,6120                                         JPW3977
 3097 ZX=ZX*.5/Z1                                                       JPW3978
      ZY=ZY*.5/Z1                                                       JPW3979
      GO TO 6120                                                        JPW3980
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 3099 ZX=(Z(II)-Z(IJ))/(2.*H)                                           JPW3981
      ZY=(Z(IK)-Z(IL))/(2.*H)                                           JPW3982
C    THE STRESS RESULTANTS ON THE SHELL ARE CALCULATED
 6120 FX1=FYY*(SQRTF((1.+ZX**2)/(1.+ZY**2)))                            JPW3983
      SYY=FXX                                                           JPW3984
      SXX=FYY                                                           JPW3985
      SXY=FXY                                                           JPW3986
      FYY=FXX*(SQRTF((1.+ZY**2)/(1.+ZX**2)))                            JPW3987
      FXX=FX1                                                           JPW3988
      FXY=-FXY                                                          JPW3989
      IY=LP(ITWO)/100                                                   JPW3990
      IX=LP(ITWO)-100*IY                                                JPW3991
      Y=IY                                                              JPW3992
      X=IX                                                              JPW3993
      X=X*H                                                             JPW3994
      Y=Y*H                                                             JPW3995
C    THE PRINCIPAL STRESS RESULTANTS AND THE ANGLE THE LARGER MAKES WITH THE X
C    AXIS ARE PRINTED OUT TOGETHER WITH THE POINT AND THE POINTS COORDINATES TO
C    WHICH THEY REFER
      COS1A=(ZX*ZY)/SQRTF((ZX**2+1.)*(ZY**2+1.))                        JPW3996
      SIN1A=SQRTF(1.-COS1A**2)                                          JPW3997
      SIN2A=2.*SIN1A*COS1A                                              JPW3998
      COS2A=COS1A**2-SIN1A**2                                           JPW3999
      IF(ABSF(2.*SIN1A*FXY+SIN2A*FYY)-.0001)6121,6121,6129              JPW4000
 6121 TAN2B=0.0                                                         JPW4001
      GO TO 6123                                                        JPW4002
 6129 IF(ABSF(2.*SIN1A*FXY+SIN2A*FYY)-ABSF(FXX+2.*FXY*COS1A+FYY*COS2A))  JPW4003
     16122,6122,6127                                                    JPW4004
 6127 COT2B=-(FXX+2.*FXY*COS1A+FYY*COS2A)/(2.*SIN1A*FXY+SIN2A*FYY)      JPW4005
      C=ATANF(COT2B)                                                    JPW4006
      B=(1.5708-C)/2.                                                   JPW4007
      GO TO 6126                                                        JPW4008
 6122 TAN2B=-(2.*SIN1A*FXY+SIN2A*FYY)/(FXX+2.*FXY*COS1A+FYY*COS2A)      JPW4009
 6123 C=ATANF (TAN2B)                                                   JPW4010
      B=C/2.                                                            JPW4011
 6126 DEGB=B*180./3.14159                                               JPW4012
      SN1=FXX*(SINF(B))**2/SIN1A+FXY*(SINF(B)*(SIN1A*COSF(B)+SINF(B)*COS JPW4013
     11A)*2.)/SIN1A+FYY*(SIN1A*COSF(B)+SINF(B)*COS1A)**2/SIN1A          JPW4014
      B=B+1.5708                                                        JPW4015
      SN2=FXX*(SINF(B))**2/SIN1A+FXY*(SINF(B)*(SIN1A*COSF(B)+SINF(B)*COS JPW4016
     11A)*2.)/SIN1A+FYY*(SIN1A*COSF(B)+SINF(B)*COS1A)**2/SIN1A          JPW4017
      PUNCH 8000,LP(ITWO),Z(ITWO),SXX,SXY,SYY,FXX,FXY,FYY,SN1,SN2,DEGB  JPW4018
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6010 PRINT 7000,LP(ITWO),X,Y,Z(ITWO),FXX,FYY,FXY,SN1,SN2,DEGB          JPW4019
     IF(LOAD-NL)6009,6005,6009                                          JPW4020
6009 REWIND 11                                                          JPW4021
6005 CONTINUE                                                           JPW4022
     PRINT 7001                                                         JPW4023
     PRINT 7002                                                         JPW4024
     DO 6211 LOAD=1,NL                                                  JPW4025
     PRINT 7010                                                         JPW4026
     PRINT 7030,LOAD                                                    JPW4027
     DO 6211 ITWO=1,IMID                                                JPW4028
     GO TO (4200,4200,4210),INTSW                                       JPW4029
4210 READ TAPE 12,ZXBC,ZYBC                                             JPW4030
     FXX=AN                                                             JPW4031
     FYY=AN                                                             JPW4032
     FXY=0.0                                                            JPW4033
     GO TO 6241                                                         JPW4034
4200 READ TAPE 12, (KFBC(I),RFXXBC(I),RFXYBC(I),RFYYBC(I),I=1,10),ZXBC  JPW4035
    1,ZYBC                                                              JPW4036
     FXX=0.                                                             JPW4037
     FXY=0.                                                             JPW4038
     FYY=0.                                                             JPW4039
     DO 6240 I=1,10                                                     JPW4040
     IF(KFBC(I)-6) 6240,6240,6230                                       JPW4041
6230 DO 6231 J=1,NP                                                     JPW4042
     IF(LP(J)-KFBC(I)) 6231,6232,6231                                   JPW4043
6231 CONTINUE                                                           JPW4044
     STOP                                                               JPW4045
6232 FXX=FXX+  Q(J,LOAD)*RFXXBC(I)                                      JPW4046
     FXY=FXY+  Q(J,LOAD)*RFXYBC(I)                                      JPW4047
     FYY=FYY+  Q(J,LOAD)*RFYYBC(I)                                      JPW4048
6240 CONTINUE                                                           JPW4049
6241 DO 6260 J=1,NS                                                     JPW4050
     IF(MCONS(1,J)-LBPS(ITWO))6260,6270,6260                            JPW4051
6260 CONTINUE                                                           JPW4052
     GO TO 6211                                                         JPW4053
6270 SNNN=FYY*SINS(J)**2+FXX*COSS(J)**2+2.*FXY*SINS(J)*COSS(J)          JPW4054
     SNNS=(FYY-FXX)*SINS(J)*COSS(J)+FXY*(COSS(J)**2-SINS(J)**2)         JPW4055
     SNNZ=-ZYBC*COSS(J)*FXX+FXY*(ZXBC*COSS(J)-ZYBC*SINS(J))+ZXBC*SINS(J JPW4056
    1)*FYY                                                              JPW4057
     PUNCH 8001,LBP(ITWO),LBPS(ITWO),XBP(ITWO),YBP(ITWO),ZBP(ITWO),FXX, JPW4058
    1FXY,FYY,ZXBC,ZYBC,SNNS,SNNZ,SNNN                                   JPW4059
     IF(LBP(ITWO))6290,6300,6290                                        JPW4060
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C    THE STRESS RESULTANTS ARE PRINTED OUT FOR EACH BOUNDARY POINT
 6290 PRINT 7040,LBP(ITWO),LBPS(ITWO),XBP(ITWO),YBP(ITWO),ZBP(ITWO),SNNS JPW4061
     1,SNNZ,SNNN                                                        JPW4062
      GO TO 6210                                                        JPW4063
C    NOTE   IF THE BOUNDARY POINT NUMBER IS BLANK, THE POINT HAS BEEN ADDED BY
C    THE PROGRAM
 6300 PRINT 7050,LBPS(ITWO),XBP(ITWO),YBP(ITWO),ZBP(ITWO),SNNS,SNNZ,SNNN JPW4064
 6210 IF(LOAD-NL)6212,6211,6211                                         JPW4065
 6212 REWIND 12                                                         JPW4066
 6211 CONTINUE                                                          JPW4067
      PRINT 7060                                                        JPW4074
C    END OF PHASE 6.   RETURN AND READ NEXT PROBLEM
      CALL CHAIN (1,B1)                                                 JPW4075
 6000 FORMAT (20X,8HSOLUTION///25X,19HFOR INTERIOR POINTS//)            JPW4076
 6001 FORMAT (15X,25HLOADING CONDITION NUMBER I1//2X,09HFOR POINT,7X,  1 JPW4077
     17HPOINT COORDINATES,13X,26HSTRESS RESULTANTS ON SHELL,7X,27HPRINCI JPW4078
     2PAL STRESS RESULTANTS,4X,5HANGLE,/3X,6HNUMBER,6X,1HX,10X,1HY,10X,1 JPW4079
     3HZ,9X,3HNXX,10X,3HNYY,10X,3HNXY,7X,7HMAXIMUM,7X,7HMINIMUM,5X,11HWI JPW4080
     4TH X AXIS//)                                                      JPW4081
 6002 FORMAT (//////1H1)                                                JPW4082
 7000 FORMAT (4X,I4,F10.2,1X,F10.2,1X,F10.2,   F12.3,1X,F12.3,1X,F12.3, JPW4083
     2  F12.3,2X,F12.3,7X,F6.2//)                                       JPW4084
 7001 FORMAT (//5X,111HWHERE NXX IS THE STRESS RESULTANT ON THE X FACE A JPW4085
     1ND HAS ITS PROJECTION ON THE X Y PLANE PARALLEL TO THE X AXIS.,//1 JPW4086
     21X,105HNYY IS THE STRESS RESULTANT ON THE Y FACE AND HAS ITS PROJE JPW4087
     3CTION ON THE X Y PLANE PARALLEL TO THE Y AXIS./)                  JPW4088
 7002 FORMAT                                          (/11X,104HNXY IS THE JPW4089
     1 STRESS RESULTANT ON THE X FACE AND HAS ITS PROJECTION ON THE X Y JPW4090
     2PLANE PARALLEL TO THE Y AXIS//10X,   103H=NYX, THE STRESS RESULTAN JPW4091
     3T ON THE Y FACE HAVING ITS PROJECTION ON THE X Y PLANE PARALLEL TO JPW4092
     4 THE X AXIS.,/1H1)                                                JPW4093
 7010 FORMAT (     //9X,29HSTRESS RESULTANTS AT BOUNDARY///)            JPW4094
 7030 FORMAT(5X,25HLOADING CONDITION NUMBER I1//05X,8HAT POINT4X,4HSIDE, JPW4095
     18X1HX11X,1HY11X,1H7,7X,20HPROJECTED TANGENTIAL,6X,8HVERTICAL, 8X,1 JPW4096
     26HPROJECTED NORMAL,/6X,6HNUMBER,4X,6HNUMBER,3X,10HCOORDINATE,2X,10 JPW4097
     3HCOORDINATE,2X,10HCOORDINATE4X,16HSTRESS RESULTANT,4X,16HSTRESS RE JPW4098
     4SULTANT,4X,16HSTRESS RESULTANT//)                                 JPW4099
 7040 FORMAT (7X,I3,7X,I3,3X,F9.2,3X,F9.2,3X,F9.2,8X,F11.4,7X,F11.4,7X,F JPW4100
     211.4//)                                                           JPW4101
 7050 FORMAT (17X,I3,3X,F9.2,3X,F9.2,3X,F9.2,8X,F11.4,7X,F11.4,7X,F11.4/ JPW4102
     2/)                                                                JPW4103
 7060 FORMAT (//20X,17HPROBLEM COMPLETED/1H1)                           JPW4104
```

```
8000 FORMAT (I4,F6.2,8F8.2,F6.2)                                        JPW4105
8001 FORMAT (2I3,3F6.2,8F7.2)                                           JPW4106
9000 FORMAT (1X,2HLP4X,1HZ,5X,4HF,YY4X,4HF,XY4X,4HF,XX4X,4HN XX4X,4HN X JPW4107
    1Y,4X,4HN YY,6X,9HPRINCIPAL,3X,5HANGLE)                             JPW4108
     END                                                                JPW4109
```

```
*     LABEL                                                             JPW2670
CTWO                                                                    JPW2671
      SUBROUTINE ALBETA(M,ALFA,BETA)                                    JPW2672
C   SUBROUTINE ALBETA RETURNS VALUES FOR ALFA AND BETA GIVEN A RELATIVE NUMBER
C   M IS THE RELATIVE NUMBER AS GIVEN
C   ALFA IS THE TAYLOR SERIES PARAMETER IN THE X DIRECTION
C   BETA IS THE TAYLOR SERIES PARAMETER IN THE Y DIRECTION AS RETURNED
      GO TO (2601,2602,2603,2604,2605,2606,2607,2608,2609,2610,2611,2612 JPW2673
     1,2613,2614,2615,2616,2617,2618,2619,2620,2621,2622,2623,2624,2625, JPW2674
     22626,2627,2628,2629,2630,2631,2632,2633,2634,2635,2636,2637,2638,2 JPW2675
     3639,2640,2641,2642,2643,2644,2645,2646,2647,2648,2649),M          JPW2676
 2601 ALFA=0.0                                                          JPW2677
      BETA= 0.0                                                         JPW2678
      RETURN                                                            JPW2679
 2602 ALFA=1.0                                                          JPW2680
      BETA= 0.0                                                         JPW2681
      RETURN                                                            JPW2682
 2603 ALFA=-1.                                                          JPW2683
      BETA=0.0                                                          JPW2684
      RETURN                                                            JPW2685
 2604 ALFA=0.0                                                          JPW2686
      BETA= 1.0                                                         JPW2687
      RETURN                                                            JPW2688
 2605 ALFA=0.0                                                          JPW2689
      BETA=-1.0                                                         JPW2690
      RETURN                                                            JPW2691
 2606 ALFA=1.0                                                          JPW2692
      BETA= 1.0                                                         JPW2693
      RETURN                                                            JPW2694
 2607 ALFA=-1.0                                                         JPW2695
      BETA=-1.0                                                         JPW2696
      RETURN                                                            JPW2697
 2608 ALFA=-1.0                                                         JPW2698
      BETA= 1.0                                                         JPW2699
      RETURN                                                            JPW2700
 2609 ALFA=1.0                                                          JPW2701
      BETA=-1.0                                                         JPW2702
      RETURN                                                            JPW2703
 2610 ALFA=2.0                                                          JPW2704
      BETA= 0.0                                                         JPW2705
      RETURN                                                            JPW2706
 2611 ALFA=-2.0                                                         JPW2707
```

```
      BETA= 0.0                                                         JPW2708
      RETURN                                                            JPW2709
 2612 ALFA=0.0                                                          JPW2710
      BETA= 2.0                                                         JPW2711
      RETURN                                                            JPW2712
 2613 ALFA=0.0                                                          JPW2713
      BETA=-2.0                                                         JPW2714
      RETURN                                                            JPW2715
 2614 ALFA=2.0                                                          JPW2716
      BETA= 1.0                                                         JPW2717
      RETURN                                                            JPW2718
 2615 ALFA=-2.0                                                         JPW2719
      BETA=-1.0                                                         JPW2720
      RETURN                                                            JPW2721
 2616 ALFA=-1.0                                                         JPW2722
      BETA= 2.0                                                         JPW2723
      RETURN                                                            JPW2724
 2617 ALFA=1.0                                                          JPW2725
      BETA= -2.0                                                        JPW2726
      RETURN                                                            JPW2727
 2618 ALFA=1.0                                                          JPW2728
      BETA= 2.0                                                         JPW2729
      RETURN                                                            JPW2730
 2619 ALFA=-1.0                                                         JPW2731
      BETA=-2.0                                                         JPW2732
      RETURN                                                            JPW2733
 2620 ALFA=2.0                                                          JPW2734
      BETA=-1.0                                                         JPW2735
      RETURN                                                            JPW2736
 2621 ALFA=-2.0                                                         JPW2737
      BETA= 1.0                                                         JPW2738
      RETURN                                                            JPW2739
 2622 ALFA= 2.0                                                         JPW2740
      BETA= 2.0                                                         JPW2741
      RETURN                                                            JPW2742
 2623 ALFA=-2.0                                                         JPW2743
      BETA=-2.0                                                         JPW2744
      RETURN                                                            JPW2745
 2624 ALFA=-2.0                                                         JPW2746
      BETA= 2.0                                                         JPW2747
      RETURN                                                            JPW2748
 2625 ALFA=+2.0                                                         JPW2749
```

```
      BETA=-2.0                                                         JPW2750
      RETURN                                                            JPW2751
 2626 ALFA=+3.0                                                         JPW2752
      BETA=+0.0                                                         JPW2753
      RETURN                                                            JPW2754
 2627 ALFA=-3.0                                                         JPW2755
      BETA=+0.0                                                         JPW2756
      RETURN                                                            JPW2757
2628  ALFA=+0.0                                                         JPW2758
      BETA=+3.0                                                         JPW2759
      RETURN                                                            JPW2760
 2629 ALFA=-0.0                                                         JPW2761
      BETA=-3.0                                                         JPW2762
      RETURN                                                            JPW2763
 2630 ALFA=+3.0                                                         JPW2764
      BETA=+1.0                                                         JPW2765
      RETURN                                                            JPW2766
2631  ALFA=-3.0                                                         JPW2767
      BETA=-1.0                                                         JPW2768
      RETURN                                                            JPW2769
2632  ALFA=-1.0                                                         JPW2770
      BETA=+3.0                                                         JPW2771
      RETURN                                                            JPW2772
 2633 ALFA=+1.0                                                         JPW2773
      BETA=-3.0                                                         JPW2774
      RETURN                                                            JPW2775
 2634 ALFA=+1.0                                                         JPW2776
      BETA=+3.0                                                         JPW2777
      RETURN                                                            JPW2778
 2635 ALFA=-1.0                                                         JPW2779
      BETA=-3.0                                                         JPW2780
      RETURN                                                            JPW2781
 2636 ALFA=+3.0                                                         JPW2782
      BETA=-1.0                                                         JPW2783
      RETURN                                                            JPW2784
 2637 ALFA=-3.0                                                         JPW2785
      BETA=+1.0                                                         JPW2786
      RETURN                                                            JPW2787
 2638 ALFA=+3.0                                                         JPW2788
      BETA=+2.0                                                         JPW2789
      RETURN                                                            JPW2790
 2639 ALFA=-3.0                                                         JPW2791
```

```
      BETA=-2.0                                                         JPW2792
      RETURN                                                            JPW2793
 2640 ALFA=-2.0                                                         JPW2794
      BETA=+3.0                                                         JPW2795
      RETURN                                                            JPW2796
 2641 ALFA=+2.0                                                         JPW2797
      BETA=-3.0                                                         JPW2798
      RETURN                                                            JPW2799
 2642 ALFA=+2.0                                                         JPW2800
      BETA=+3.0                                                         JPW2801
      RETURN                                                            JPW2802
 2643 ALFA=-2.0                                                         JPW2803
      BETA=-3.0                                                         JPW2804
      RETURN                                                            JPW2805
 2644 ALFA=-3.0                                                         JPW2806
      BETA=+2.0                                                         JPW2807
      RETURN                                                            JPW2808
 2645 ALFA=+3.0                                                         JPW2809
      BETA=-2.0                                                         JPW2810
      RETURN                                                            JPW2811
 2646 ALFA=+4.0                                                         JPW2812
      BETA=+0.0                                                         JPW2813
      RETURN                                                            JPW2814
 2647 ALFA=-4.0                                                         JPW2815
      BETA=+0.0                                                         JPW2816
      RETURN                                                            JPW2817
 2648 ALFA=-0.0                                                         JPW2818
      BETA=+4.0                                                         JPW2819
      RETURN                                                            JPW2820
 2649 ALFA=+0.0                                                         JPW2821
      BETA=-4.0                                                         JPW2822
      RETURN                                                            JPW2823
      END                                                               JPW2824
```

```
*     LABEL                                                             JPW2884
CTWO                                                                    JPW2885
      SUBROUTINE CHECK (A,B,KZ,KZO,JIM1,JIM2,JIM3,IPRINT,LP,ITWO)       JPW2886
C   SUBROUTINE CHECK BACKSUBSTITUTES THE DIFFERENCEMOLEKULES AND CHECKS FOR
C      ROUNDOFF ERROR
      DIMENSION A(10,35),B(10,5),KZ(37),KZO(37),LP(561)                 JPW2887
      DO 100 I=1,JIM1                                                   JPW2888
      IF(KZO(I)-KZ(I)) 90,100,90                                        JPW2889
   90 DO 110 J=I,JIM2                                                   JPW2890
      IF(KZO(J)-KZ(I))110,120,110                                       JPW2891
  120 ITEMP=KZO(I)                                                      JPW2892
      KZO(I)=KZO(J)                                                     JPW2893
      KZO(J)=ITEMP                                                      JPW2894
      DO 130 K=1,JIM1                                                   JPW2895
      TEMP=A(K,J)                                                       JPW2896
      A(K,J)=A(K,I)                                                     JPW2897
  130 A(K,I)=TEMP                                                       JPW2898
      GO TO 100                                                         JPW2899
  110 CONTINUE                                                          JPW2900
  100 CONTINUE                                                          JPW2901
      CALL MATMPL (A,B,JIM1,JIM1,JIM3,1)                                JPW2902
      DO 170 I=1,3                                                      JPW2903
      DO 170 J=1,JIM1                                                   JPW2904
      IF(ABSF(A(J,I))-.0001) 170,180,180                                JPW2905
  180 IF(ABSF(A(J,I)-1.000)-.0001) 170,190,190                          JPW2906
  170 CONTINUE                                                          JPW2907
      IF(IPRINT) 150,160,150                                            JPW2908
  190 PRINT 3,LP(ITWO)                                                  JPW2909
  160 PRINT 2                                                           JPW2910
      DO 140 I=1,JIM3                                                   JPW2911
  140 PRINT 1,(A(J,I),J=1,JIM1)                                         JPW2912
  150 RETURN                                                            JPW2913
    1 FORMAT ( 10F12.6)                                                 JPW2914
    2 FORMAT (  /10X,35HBACK SUBSTITUTION GIVES THIS RESULT/ )          JPW2915
    3 FORMAT (///10X,51HWARNING.  ERRORS EXIST IN THE DERRIVATIVES AT PO JPW2916
     1INT,I6//)                                                         JPW2917
      END                                                               JPW2918
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```
*     LABEL
CTWO                                                                    JPW2858
      SUBROUTINE CLGRID(LP,NP,LPC)                                      JPW2859
C   SUBROUTINE CLGRID CLASSIFIES ALL THE GRID POINTS DEPENDING ON HOW MANY OF  JPW2860
C   THE SURROUNDING EIGHT RELATIVE POINTS LIE INSIDE THE SHELL
C   IF LPC=1, ALL THE POINTS ARE INSIDE THE SHELL
C   IF LPC=2, ONLY SEVEN OF THE SURROUNDING POINTS LIE WITHIN THE BOUNDARY
C   IF LPC=3, LESS THAN SEVEN OF THE SURROUNDING POINTS ARE IN LP
C   LP IS THE  LIST OF ABSOLUTE POINT NUMBERS
C   NP IS THE TOTAL NUMBER OF INTERIOR POINTS AS READ IN
C   LPC IS THE RETURNED POINTER
      DIMENSION LP(50),LPC(50)
      DO 2103 IGRID=1,NP                                                JPW2861
      IPOINT=1                                                          JPW2862
      DO 2104 I=1,NP                                                    JPW2863
      IF(LP(I)-LP(IGRID)+  1) 2106,2105,2106                            JPW2864
 2106 IF(LP(I)-LP(IGRID)-  1) 2107,2105,2107                            JPW2865
 2107 IF(LP(I)-LP(IGRID)+100) 2108,2105,2108                            JPW2866
 2108 IF(LP(I)-LP(IGRID)-100) 2109,2105,2109                            JPW2867
 2109 IF(LP(I)-LP(IGRID)+101) 2110,2105,2110                            JPW2868
 2110 IF(LP(I)-LP(IGRID)-101) 2111,2105,2111                            JPW2869
 2111 IF(LP(I)-LP(IGRID)+ 99) 2112,2105,2112                            JPW2870
 2112 IF(LP(I)-LP(IGRID)- 99) 2104,2105,2104                            JPW2871
 2105 IPOINT=IPOINT+1                                                   JPW2872
 2104 CONTINUE                                                          JPW2873
      IF(IPOINT-8) 2113,2114,2115                                       JPW2874
 2113 LPC(IGRID)=3                                                      JPW2875
      GO TO 2103                                                        JPW2876
 2114 LPC(IGRID)=2                                                      JPW2877
      GO TO 2103                                                        JPW2878
 2115 LPC(IGRID)=1                                                      JPW2879
 2103 CONTINUE                                                          JPW2880
      RETURN                                                            JPW2881
      END                                                               JPW2882
                                                                        JPW2883
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*       FAP                                                             JPW2017
        ENTRY   DIRECT                                                  JPW2020
        ENTRY   DIREC2                                                  JPW2021
        ENTRY   LIST                                                    JPW2022
DIRECT  DEC     12                                                      JPW2023
        BCI     1,DESIGN                                                JPW2024
        BCI     1,0DESIG                                                JPW2025
        BCI     1,00DESI                                                JPW2026
        BCI     1,000DES                                                JPW2027
        BCI     1,0000DE                                                JPW2028
        BCI     1,00000D                                                JPW2029
        BCI     1,ANALYS                                                JPW2030
        BCI     1,0ANALY                                                JPW2031
        BCI     1,00ANAL                                                JPW2032
        BCI     1,000ANA                                                JPW2033
        BCI     1,0000AN                                                JPW2034
        BCI     1,00000A                                                JPW2035
DIREC2  DEC     12                                                      JPW2036
        BCI     1,FUNCTI                                                JPW2037
        BCI     1,UNCTIO                                                JPW2038
        BCI     1,NCTION                                                JPW2039
        BCI     1,CTIONO                                                JPW2040
        BCI     1,TIONOO                                                JPW2041
        BCI     1,IONOOO                                                JPW2042
        BCI     1,POINTS                                                JPW2043
        BCI     1,0POINT                                                JPW2044
        BCI     1,00POIN                                                JPW2045
        BCI     1,000POI                                                JPW2046
        BCI     1,0000PO                                                JPW2047
        BCI     1,00000P                                                JPW2048
LIST    DEC     12                                                      JPW2049
        BCI     1,SHELLO                                                JPW2050
        BCI     1,0SHELL                                                JPW2051
        BCI     1,00SHEL                                                JPW2052
        BCI     1,000SHE                                                JPW2053
        BCI     1,0000SH                                                JPW2054
        BCI     1,00000S                                                JPW2055
        BCI     1,PROBLE                                                JPW2056
        BCI     1,0PROBL                                                JPW2057
        BCI     1,00PROB                                                JPW2058
        BCI     1,000PRO                                                JPW2059
        BCI     1,0000PR                                                JPW2060
        BCI     1,00000P                                                JPW2061
        END                                                             JPW2062
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```
*     LABEL                                                             JPW2825
CTWO                                                                    JPW2826
      SUBROUTINE DIST (CPC,H,LP,I,MCONS,IDIST,D,XD,YD,X1,X2,Y1,Y2,X3,Y3, JPW2827
     1NS,MC)                                                            JPW2828
C    SUBROUTINE DIST CALCULATES THE DISTANCE OF AN ABSOLUTE POINT LP(I)FROM SIDE
C    OF ADDRESS (1,IDIST) IN THE CONNECTIVITY MATRIX MCONS
C    CPC IS THE MATRIX OF CORNER POINT COORDINATES
C    MC IS THE LIST OF CORNER POINT NUMBERS
C    NS=THE NUMBER OF SIDES
C    XD AND YD ARE THE COORDINATES OF THE JUNCTION BETWEEN THE NORMAL AND SIDE
C    X1,Y1 AND X2,Y2 ARE THE COORDINATES OF THE CORNER POINTS WHICH DEFINE THE
C    SIDE IN QUESTION
C    D IS THE RETURNED VALUE OF THE DISTANCE
      DIMENSION CPC(100,3),LP(10),MCONS(3,10),MC(10)                    JPW2829
      ISIDE=MCONS(1,IDIST)                                              JPW2830
      JSID2=MCONS(2,IDIST)                                              JPW2831
      KSID2=MCONS(3,IDIST)                                              JPW2832
      DO 2310 IS=1,NS                                                   JPW2833
      IF(MC(IS)-JSID2)2320,2330,2320                                    JPW2834
 2320 IF(MC(IS)-KSID2)2310,2340,2310                                    JPW2835
 2330 JSIDE=IS                                                          JPW2836
      GO TO 2310                                                        JPW2837
 2340 KSIDE=IS                                                          JPW2838
 2310 CONTINUE                                                          JPW2839
      X1=CPC(JSIDE,1)                                                   JPW2840
      Y1=CPC(JSIDE,2)                                                   JPW2841
      X2=CPC(KSIDE,1)                                                   JPW2842
      Y2=CPC(KSIDE,2)                                                   JPW2843
      CONX=LP(I)                                                        JPW2844
      ICONX=LP(I)/100                                                   JPW2845
      CON2=ICONX                                                        JPW2846
      CONX=(CONX-CON2*100.)                                             JPW2847
      CONY=CON2                                                         JPW2848
      X3=CONX*H                                                         JPW2849
      Y3=CONY*H                                                         JPW2850
      XD=(X3*((X1-X2)**2)+X1*((Y1-Y2)**2)-(X1-X2)*(Y1-Y2)*(Y1-Y3))/(((X1 JPW2851
     1-X2)**2)+((Y1-Y2)**2))                                            JPW2852
      YD=(((Y3*(Y2-Y1)**2)+(Y1*(X2-X1)**2)+(X3*(Y2-Y1)*(X2-X1))-(X1*(X2-X JPW2853
     11 )*(Y2-Y1)))/(((Y2-Y1)**2)+((X2-X1)**2))                         JPW2854
      D=SQRTF((X3-XD)**2+(Y3-YD)**2)                                    JPW2855
      RETURN                                                            JPW2856
      END                                                               JPW2857
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```
*     LABEL                                                             JPW2465
CTWO                                                                    JPW2466
      SUBROUTINE FINDZD(MCONS,LBPS,XBP,YBP,ZBP,SINS,XD,YD,IMID,IDIST,ZD) JPW2467
C   SUBROUTINE FINDZD DETERMINES THE VALUE OF Z COORDINATE FOR ANY GIVEN X AND Y
C   COORDINATES ON THE  SIDE GIVEN IN ADDRESS (1,DIST) IN  THE CONNECTIVITY
C   MATRIX   (MCONS)
C   LBPS IS A LIST OF SIDE NUMBERS WITH WHICH EACH BOUNDARY POINT IS ASSOCIATED
C   XBP IS THE X COORDINATE OF THE BOUNDARY POINT
C   YBP AND ZBP ARE THE Y AND Z COORDINATES OF THE BOUNDARY POINT
C   SINS IS A LIST OF THE SINES OF THE ANGLE BETWEEN THE SIDES AND THE X AXIS
C   IMID IS THE TOTAL NUMBER OF BOUNDARY POINTS
C   ZD IS THE RETURNED Z COORDINATE
      DIMENSION MCONS(3,10),LBPS(10),XBP(10),YBP(10),ZBP(10),SINS(10)    JPW2468
      ISIDE=MCONS(1,IDIST)                                              JPW2469
      DO 2810 JZ=1,IMID                                                 JPW2470
      IZ=JZ                                                             JPW2471
      IF(LBPS(JZ)-LBPS(JZ+1)) 2810,2805,2810                            JPW2472
 2805 IF(LBPS(JZ)-ISIDE) 2810,2820,2810                                 JPW2473
 2820 IF(ABSF(SINS(IDIST))-.707) 2830,2830,2800                         JPW2474
 2830 IF(ABSF(XBP(JZ))-ABSF(XD)) 2840,2860,2850                         JPW2475
 2840 IF(ABSF(XBP(JZ+1))-ABSF(XD)) 2810,2860,2860                       JPW2476
 2850 IF(ABSF(XBP(JZ+1))-ABSF(XD)) 2860,2860,2810                       JPW2477
 2860 ZD=(XD-XBP(JZ))*(ZBP(JZ)-ZBP(JZ+1))/(XBP(JZ)-XBP(JZ+1))+ZBP(JZ)  JPW2478
      RETURN                                                            JPW2479
 2800 IF(ABSF(YBP(IZ))-ABSF(YD)) 2880,2890,2870                         JPW2480
 2870 IF(ABSF(YBP(IZ+1))-ABSF(YD)) 2890,2890,2810                       JPW2481
 2880 IF(ABSF(YBP(IZ+1))-ABSF(YD)) 2810,2890,2890                       JPW2482
 2890 ZD=(YD-YBP(JZ))*(ZBP(JZ)-ZBP(JZ+1))/(YBP(JZ)-YBP(JZ+1))+ZBP(JZ)  JPW2483
      RETURN                                                            JPW2484
 2810 CONTINUE                                                          JPW2485
      ZD=10.**10                                                        JPW2486
      RETURN                                                            JPW2487
      END                                                               JPW2488
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```
*     LABEL
CTHR                                                                    JPW3011
D     SUBROUTINE INVERT (A,JIM1,IEXQ)                                   JPW3012
C   SUBROUTINE INVERT WILL INVERT A MATRIX USING PIVOTAL CONDENSATION AND JPW3013
C         DOUBLE PRECISION
C   MAX. SIZE = 61*61
D     DIMENSION A(60,60)
      DIMENSION IVECT(61),KVECT(61)                                     JPW3014
      JIM2=JIM1                                                         JPW3015
      DO 2525 I=1,JIM1                                                  JPW3016
      IVECT(I)=I                                                        JPW3017
 2525 KVECT(I)=I                                                        JPW3018
 2527 J=1                                                               JPW3019
D2515 PIVOT=0.0                                                         JPW3020
      DO 2500 JP=J,JIM1                                                 JPW3021
      DO 2500 IP=J,JIM2                                                 JPW3022
D     IF(ABSF(PIVOT)-ABSF(A(JP,IP))) 2501,2500,2500                     JPW3023
D2501 PIVOT=A(JP,IP)                                                    JPW3024
      IPIV=JP                                                           JPW3025
      JPIV=IP                                                           JPW3026
 2500 CONTINUE                                                          JPW3027
D     IF(ABSF(PIVOT)-.00000100100)2518,2518,2502                        JPW3028
 2502 DO 2504 IEXC=1,JIM1                                               JPW3029
D     ATEMP=A(IEXC,JPIV)                                                JPW3030
D     A(IEXC,JPIV)=A(IEXC,J)                                            JPW3031
D2504 A(IEXC,J)=ATEMP                                                   JPW3032
      DO 2505 JEXC=1,JIM2                                               JPW3033
D     ATEMP=A(IPIV,JEXC)                                                JPW3034
D     A(IPIV,JEXC)=A(J,JEXC)                                            JPW3035
D2505 A(J,JEXC)=ATEMP                                                   JPW3036
      ITEMP=KVECT(J)                                                    JPW3037
      KVECT(J)=KVECT(JPIV)                                              JPW3038
      KVECT(JPIV)=ITEMP                                                 JPW3039
      ITEMP=IVECT(J)                                                    JPW3040
      IVECT(J)=IVECT(IPIV)                                              JPW3041
      IVECT(IPIV)=ITEMP                                                 JPW3042
      DO 2506 IKELR=1,JIM2                                              JPW3043
D2506 A(J,IKELR)=A(J,IKELR)/(-1.*PIVOT)                                 JPW3044
      K=J+1                                                             JPW3045
      DO 2530 IELSE=1,JIM1                                              JPW3046
      IF(IELSE-J)2508,2530,2508                                         JPW3047
 2508 DO 2507 JELSE=1,JIM2                                              JPW3048
                                                                        JPW3049
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      IF(JELSE-J) 2509,2507,2509                                        JPW3050
D2509 A(IELSE,JELSE)=A(IELSE,JELSE)+(A(IELSE,J)*A(J,JELSE))              JPW3051
 2507 CONTINUE                                                          JPW3052
 2530 CONTINUE                                                          JPW3053
      DO 2510 ICOL=1,JIM1                                               JPW3054
D2510 A(ICOL,J)=A(ICOL,J)/PIVOT                                         JPW3055
D     A(J,J)=+1.0/PIVOT                                                 JPW3056
      J=J+1                                                             JPW3057
      IF(J-JIM1) 2515,2515,2511                                         JPW3058
 2511 DO 2521 K=1,JIM1                                                  JPW3059
      DO 2513 I=1,JIM2                                                  JPW3060
      IF(IVECT(I)-K) 2513,2514,2513                                     JPW3061
 2514 DO 2516 I1=1,JIM1                                                 JPW3062
D     ATEMP=A(I1,K)                                                     JPW3063
D     A(I1,K)=A(I1,I)                                                   JPW3064
D2516 A(I1,I)=ATEMP                                                     JPW3065
      ITEMP=IVECT(I)                                                    JPW3066
      IVECT(I)=IVECT(K)                                                 JPW3067
      IVECT(K)=ITEMP                                                    JPW3068
 2513 CONTINUE                                                          JPW3069
 2521 CONTINUE                                                          JPW3070
      DO 2522 K=1,JIM1                                                  JPW3071
      DO 2512 I=1,JIM1                                                  JPW3072
      IF(KVECT(I)-K) 2512,2503,2512                                     JPW3073
 2503 DO 2517 I1=1,JIM2                                                 JPW3074
D     ATEMP=A(K,I1)                                                     JPW3075
D     A(K,I1)=A(I,I1)                                                   JPW3076
D2517 A(I,I1)=ATEMP                                                     JPW3077
      ITEMP=KVECT(I)                                                    JPW3078
      KVECT(I)=KVECT(K)                                                 JPW3079
      KVECT(K)=ITEMP                                                    JPW3080
 2512 CONTINUE                                                          JPW3081
 2522 CONTINUE                                                          JPW3082
      RETURN                                                            JPW3083
 2518 IRRR=JIM1-J+1                                                     JPW3084
      PRINT 2529,IRRR                                                   JPW3085
      IEXQ=1                                                            JPW3086
      CALL CHAIN (1,B1)                                                 JPW3087
 2529 FORMAT (1H1,10X,64HTHE SYSTEM OF DIFFERENCE EQUATIONS FOR THIS PRO JPW3088
     1BLEM IS SINGULAR. //15X,28HTHE DEGREE OF SINGULARITY IS,I4,////10X JPW3089
     2,20HEXECUTION TERMINATED//1H1)                                    JPW3090
      END                                                               JPW3091
```

```
*     LABEL                                                             JPW2489
CTWO                                                                    JPW2490
      SUBROUTINE JUDY(A,JIM1,JIM4,KVECT,NBC,LP,ITWO,IEXQ,NRHS)          JPW2491
C   JUDY IS A WONDERFUL GIRL AND PUNCHED ALL THE CARDS AND SO WE NAME THIS,THE
C   MOST IMPORTANT SUBROUTINE AFTER HER.
C   SUBROUTINE JUDY SOLVES A SET OF EQUATIONS IDENTICALLY FOR THE FINITE DIFFER-
C   ENCE MOLECULE AT POINT NUMBER ITWO
C   A=THE AUGMENTED MATRIX (INCLUDES R.H.S. AND L.H.SIDES)
C   JIM1=THE FIRST DIMENSION OF THE AUGMENTED MATRIX
C   JIM2=THE SECOND DIMENSION OF THE AUGMENTED MATRIX
C   KVECT=THE VECTOR OF UNKNOWNS
C   NBC=THE NUMBER OF BOUNDARY CONDITIONS FORMULATED AT POINT NUMBER ITWO
C   LP IS THE LIST OF POINTS    IEXQ IS THE EXECUTION DELETED POINTER
      DIMENSION A(10,42),KVECT(37),LP(1000)                             JPW2492
      IF(NRHS-3) 2560,2570,2570                                         JPW2493
 2570 NCHEC=3                                                           JPW2494
      GO TO 2580                                                        JPW2495
 2560 NCHEC=NRHS                                                        JPW2496
 2580 JIM2=JIM4+NRHS                                                    JPW2497
C   CHANGE THE SIGN OF ALL RIGHT HAND SIDES
      DO 2529 I=1,JIM1                                                  JPW2498
      DO 2529 K=1,NRHS                                                  JPW2499
      JIM3=JIM4+K                                                       JPW2500
 2529 A(I,JIM3)=-A(I,JIM3)                                              JPW2501
C   CHECK NBC=THE NUMBER OF BOUNDARY CONDITIONS FORMULATED AT THIS POINT
      IF(NBC) 2524,2524,2525                                            JPW2502
 2525 NPS=NBC                                                           JPW2503
      GO TO 2527                                                        JPW2504
 2524 NPS=1                                                             JPW2505
 2527 J=1                                                               JPW2506
 2515 PIVOT=0.0                                                         JPW2507
C   SEARCH THE MATRIX UP TO NPS COLUMN AND IN ALL ROWS FOR THE LARGEST ELEMENT
      DO 2500 IP=J,NPS                                                  JPW2508
      DO 2500 JP=J,JIM1                                                 JPW2509
      IF(ABSF(PIVOT)-ABSF(A(JP,IP))) 2501,2500,2500                     JPW2510
 2501 PIVOT=A(JP,IP)                                                    JPW2511
C   PIVOT=THE LARGEST ABSOLUTE ELEMENT IN THIS SUB-MATRIX
      IPIV=JP                                                           JPW2512
      JPIV=IP                                                           JPW2513
C   IPIV=THE FIRST ADDRESS OF THIS ELEMENT  JPIV=THE SECOND ADDRESS
 2500 CONTINUE                                                          JPW2514
      IF(ABSF(PIVOT)-.10000)2541,2541,2502                              JPW2515
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C    MOVE THE PIVOT INTO POSITION (J,J) OF THE MATRIX
 2502 DO 2504 IEXC=1,JIM1                                              JPW2516
      ATEMP=A(IEXC,JPIV)                                               JPW2517
      A(IEXC,JPIV)=A(IEXC,J)                                           JPW2518
 2504 A(IEXC,J)=ATEMP                                                  JPW2519
      DO 2505 JEXC=1,JIM2                                              JPW2520
      ATEMP=A(IPIV,JEXC)                                               JPW2521
      A(IPIV,JEXC)=A(J,JEXC)                                           JPW2522
 2505 A(J,JEXC)=ATEMP                                                  JPW2523
C    ADJUST KVECT=THE VECTOR OF UNKNOWNS ACCORDINGLY
      ITEMP=KVECT(J)                                                   JPW2524
      KVECT(J)=KVECT(JPIV)                                             JPW2525
      KVECT(JPIV)=ITEMP                                                JPW2526
C    CALCULATE THE ELEMENTS OF THE PIVOT ROW (KELLER ROW)
      DO 2506 IKELR=1,JIM2                                             JPW2527
 2506 A(J,IKELR)=A(J,IKELR)/(-1.*PIVOT)                                JPW2528
C    CALCULATE THE ELEMENTS ELSEWHERE IN THE MATRIX USING THE PIVOT ROW AND COL.
      K=J+1                                                            JPW2529
      DO 2507 IELSE=1,JIM1                                             JPW2530
      IF(IELSE-J)2508,2507,2508                                        JPW2531
 2508 DO 2509 JELSE=K,JIM2                                             JPW2532
 2509 A(IELSE,JELSE)=A(IELSE,JELSE)+(A(IELSE,J)*A(J,JELSE))            JPW2533
 2507 CONTINUE                                                         JPW2534
C    CALCULATE THE ELEMENTS OF THE NEW PIVOT COLUMN
      DO 2510 ICOL=1,JIM1                                              JPW2535
 2510 A(ICOL,J)=A(ICOL,J)/PIVOT                                        JPW2536
C    CALCULATE THE NEW VALUE OF A(J,J)
      A(J,J)=+1.0/PIVOT                                                JPW2537
      J=J+1                                                            JPW2538
      IF(J-JIM1-1)2511,2512,2512                                       JPW2539
 2511 IF(J-NPS-1)2513,2514,2514                                        JPW2540
C    IF WE HAVE RUN OUT OF SPACE TO SEARCH FOR A NEW PIVOT INCREMENT NPS
 2514 NPS=NPS+1                                                        JPW2541
 2513 IF(NPS-1-JIM4) 2515,2503,2503                                    JPW2542
 2503 DO 2516 I=J,JIM1                                                 JPW2543
      DO 2516 K=1,NCHEC                                                JPW2544
      JIM3=JIM4+K                                                      JPW2545
      IF(ABSF(A(I,JIM3))-.010000) 2516,2516,2521                       JPW2546
 2516 CONTINUE                                                         JPW2547
 2521 CONTINUE                                                         JPW2548
C    IF ALL THE EQUATIONS ARE SATISFIED IDENTICALLY WITHOUT THE NEED TO CALCULATE
C    ALL THE UNKNOWNS, FILL THE REST OF KVECT WITH ZEROS
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2520 DO 2522 I=J,JIM4                                          JPW2549
2522 KVECT(I)=0                                                JPW2550
     DO 2517 I=J,JIM1                                          JPW2551
     DO 2517 K=1,NRHS                                          JPW2552
     JIM3=JIM4+K                                               JPW2553
2517 A(I,JIM3)=0.0                                             JPW2554
2512 RETURN                                                    JPW2555
2541 DO 2543 I=1,JIM1                                          JPW2556
     DO 2542 K=1,NCHFC                                         JPW2557
     JIM3=JIM4+K                                               JPW2558
     IF(ABSF(A(I,JIM3))-.0001) 2542,2542,2514                  JPW2559
2542 CONTINUE                                                  JPW2560
2543 CONTINUE                                                  JPW2561
     GO TO 2520                                                JPW2562
     END                                                       JPW2563
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*       LIST8                                                           JPW1606
*       FAP                                                             JPW1607
*        SUBROUTINE MATCH  R.D.LOGCHER  VERSION CORRECTED 1-15-64       JPW1608
         COUNT    385                                                   JPW1609
         LBL      MATCH                                                 JPW1610
         ENTRY    MATCH                                                 JPW1611
MATCH    SXA      BACK,4                                                JPW1612
         SXA      BACK+2,2                                              JPW1613
         SXA      BACK+3,1                                              JPW1614
         LDQ      SAVE                                                  JPW1615
 WORD    AXT      **,1                                                  JPW1616
LETTER   AXT      **,2                                                  JPW1617
         PXA                                                            JPW1618
         LGL      36                                                    JPW1619
         LAS      =0607777777777                                        JPW1620
         TRA      *+2                                                   JPW1621
         TRA      SAL                                                   JPW1622
         LGR      36                                                    JPW1623
 CHKT    CLA*     3,4                                                   JPW1624
         SUB      ONE                                                   JPW1625
         TZE      NCARD                    NEW CARD                     JPW1626
         STZ      DICK                                                  JPW1627
         TMI      NF                       NEW FIELD                    JPW1628
         SUB      THREE                                                 JPW1629
         TMI      NUMB+1                   NUMBER ONLY EXPECTED         JPW1630
         TNZ      BUFAD                    BUFFER ADDRESS FOR CARD TRANSMISS JPW1631
         TSX      STB,4                                                 JPW1632
 STF     PXA                               STRIP ONE LOGICAL FIELD      JPW1633
         LGL      6                                                     JPW1634
         LAS      BLANK                                                 JPW1635
         TRA      *+2                                                   JPW1636
         TRA      BLK1                                                  JPW1637
         LAS      COMMA                                                 JPW1638
         TRA      *+2                                                   JPW1639
         TRA      BLK1                                                  JPW1640
         TIX      STF,2,1                                               JPW1641
         TSX      NWD,4                                                 JPW1642
         TRA      STF                                                   JPW1643
 BLK1    LGR      6                                                     JPW1644
 NF      TSX      STB,4                    EXAMINE ONE FIELD            JPW1645
         STZ      TEMP                                                  JPW1646
         PXA                                                            JPW1647
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        LGL     6                                                   JPW1648
        LAS     =0000000000040          MINUS                       JPW1649
        TRA     *+2                                                 JPW1650
        TRA     NUMB                    NUMBER NEXT                 JPW1651
        LAS     =0000000000033          DECIMAL                     JPW1652
        TRA     *+2                                                 JPW1653
        TRA     NUMB                                                JPW1654
        LAS     =0000000000020                                      JPW1655
        TRA     *+3                                                 JPW1656
        NOP                                                         JPW1657
        TRA     NUMB                                                JPW1658
        AXT     6,4                                                 JPW1659
LPNF    LGR     6                                                   JPW1660
        CAL     TEMP                                                JPW1661
        LGL     6                                                   JPW1662
        SLW     TEMP                                                JPW1663
INLP    TIX     *+4,2,1                                             JPW1664
        SXA     *+2,4                                               JPW1665
        TSX     NWD,4                                               JPW1666
        AXT     **,4                                                JPW1667
        PXA                                                         JPW1668
        LGL     6                                                   JPW1669
        LAS     BLANK                                               JPW1670
        TRA     *+2                                                 JPW1671
        TRA     BLK2                                                JPW1672
        LAS     COMMA                                               JPW1673
        TRA     *+2                                                 JPW1674
        TRA     BLK2                                                JPW1675
        TIX     LPNF,4,1                                            JPW1676
        TRA     INLP                                                JPW1677
BLK2    LGR     6                                                   JPW1678
        SXA     WORD,1                                              JPW1679
        SXA     LETTER,2                                            JPW1680
        LXA     BACK,4                                              JPW1681
        CLA*    1,4                                                 JPW1682
        STA     *+1                                                 JPW1683
ADLIST  CLA     **                                                  JPW1684
        PAX     ,1                                                  JPW1685
        ADD     *-2                                                 JPW1686
        ADD     =1                                                  JPW1687
        STA     *+8                                                 JPW1688
        CAL     TEMP                                                JPW1689
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        LAS     =0000000002446                                          JPW1690
        TRA     *+2                                                     JPW1691
        TRA     DITTO                   FIELD CONTAINS DITTO            JPW1692
        LAS     =0002431636346                                          JPW1693
        TRA     *+2                                                     JPW1694
        TRA     DITTO                   FIELD CONTAINS DITTO            JPW1695
        LAS     **,1                                                    JPW1696
        TRA     *+2                                                     JPW1697
        TRA     FOUND                                                   JPW1698
        TIX     *-3,1,1                                                 JPW1699
        SLW*    2,4                                                     JPW1700
        CLA     FOUR                                                    JPW1701
        TRA     BACK+1                                                  JPW1702
FOUND   PXA     ,1                                                      JPW1703
        SSM                                                             JPW1704
        ADD     =1                                                      JPW1705
        ADD*    ADLIST                                                  JPW1706
        ALS     18                                                      JPW1707
        STO*    2,4                                                     JPW1708
        CLA     FIVE                                                    JPW1709
        TRA     BACK+1                                                  JPW1710
DITTO   CLA     SIX                                                     JPW1711
        TRA     BACK+1                                                  JPW1712
NCARD   ZET     DICK                                                    JPW1713
        TRA     CONTER-1                                                JPW1714
        TXH     READC,1,1                                               JPW1715
        TXL     READC,2,5                                               JPW1716
        PXA                             NEW CARD ALREADY READ           JPW1717
        LGL     6                                                       JPW1718
        LAS     =054                    * FOR COMMENT CARD              JPW1719
        TRA     *+2                                                     JPW1720
        TRA     READC                                                   JPW1721
        LAS     =053                    $ FOR CONTINUATION CARD         JPW1722
        TRA     *+2                                                     JPW1723
        TRA     CONTER                  CONTINUATION CARD ERROR-NOT RIGHT JPW1724
        LGR     6                                                       JPW1725
        TRA     NF                                                      JPW1726
        STZ     DICK                                                    JPW1727
CONTER  CAL     =0532551514651                                          JPW1728
        LXA     BACK,4                                                  JPW1729
        SLW*    2,4                                                     JPW1730
        TNX     *+1,2,1                                                 JPW1731
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        SXA     WORD,1                                  JPW1732
        SXA     LETTER,2                                JPW1733
        CLA     FOUR                                    JPW1734
BACK    AXT     **,4                                    JPW1735
        STQ     SAVE                                    JPW1736
        AXT     **,2                                    JPW1737
        AXT     **,1                                    JPW1738
        TRA     4,4                                     JPW1739
NUMB    LGR     6                                       JPW1740
RFLN    CLA     =1                                      JPW1741
        STO     FLOO                                    JPW1742
        STZ     PTPLC                                   JPW1743
        STZ     BCDN                                    JPW1744
        STZ     BCDN+1                                  JPW1745
        STZ     SIGN                                    JPW1746
        AXT     0,4                                     JPW1747
        TRA     INTO                                    JPW1748
ONCON   TIX     INTO,2,1                                JPW1749
        SXA     *+2,4                                   JPW1750
        TSX     NWD,4                                   JPW1751
        AXT     **,4                                    JPW1752
        PXA                                             JPW1753
        LGL     36                                      JPW1754
        LAS     =0607777777777                          JPW1755
        TRA     *+2                                     JPW1756
        TRA     STRD-1                                  JPW1757
        LGR     36                                      JPW1758
INTO    PXA                                             JPW1759
        LGL     6                                       JPW1760
        LAS     =0000000000040                          JPW1761
        TRA     *+2                                     JPW1762
        TRA     ADSN                                    JPW1763
        LAS     =0000000000014                          JPW1764
        TRA     TSTPT                                   JPW1765
        TRA     ADSN                                    JPW1766
        TRA     NBD                                     JPW1767
ADSN    CLA     =1                                      JPW1768
        STO     SIGN                                    JPW1769
        TRA     ONCON                                   JPW1770
NBD     LAS     =0000000000012                          JPW1771
        TRA     ONCON                                   JPW1772
        TRA     ONCON                                   JPW1773
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        TXI     *+1,4,1                                         JPW1774
        LGR     6                                               JPW1775
        PXA     ,4                                              JPW1776
        SUB     =7                                              JPW1777
        TPL     SEWD                                            JPW1778
        CAL     BCDN                                            JPW1779
        LGL     6                                               JPW1780
        SLW     BCDN                                            JPW1781
        TRA     ONCON                                           JPW1782
SEWD    SUB     =2                                              JPW1783
        TPL     PTOUT                                           JPW1784
        CAL     BCDN+1                                          JPW1785
        LGL     6                                               JPW1786
        SLW     BCDN+1                                          JPW1787
        TRA     ONCON                                           JPW1788
PTOUT   AXT     8,4                                             JPW1789
        TRA     TESNU                                           JPW1790
TSTPT   LAS     =0000000000033                                  JPW1791
        TRA     BLK7                                            JPW1792
        TRA     SPT                                             JPW1793
        TRA     BLK7                                            JPW1794
SPT     SXA     PTPLC,4                                         JPW1795
        STZ     FLOO                                            JPW1796
        TRA     ONCON                                           JPW1797
BLK7    PXA     ,4                                              JPW1798
        TZE     ONCON                                           JPW1799
        TRA     STRD+1                                          JPW1800
TESNU   PXA                                                     JPW1801
        LGL     6                                               JPW1802
        LAS     =0000000000011                                  JPW1803
        TRA     STRD                                            JPW1804
        NOP                                                     JPW1805
INTB    TIX     TESNU,2,1                                       JPW1806
        SXA     *+2,4                                           JPW1807
        TSX     NWD,4                                           JPW1808
        AXT     **,4                                            JPW1809
        TRA     TESNU                                           JPW1810
        LGR     30                                              JPW1811
STRD    LGR     6                                               JPW1812
        TXL     NFND,4,0                                        JPW1813
        PXA     ,4                                              JPW1814
        SUB     PTPLC                                           JPW1815
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        STO     PTPLC                   JPW1816
        STQ     SAVE                    JPW1817
        SXA     LETTER,2                JPW1818
        STZ     FXANS                   JPW1819
        AXT     0,2                     JPW1820
NUMD    PXA     ,4                      JPW1821
        SUB     =7                      JPW1822
        TMI     INLOP                   JPW1823
        ADD     =1                      JPW1824
        PAX     ,4                      JPW1825
        CLA     =1                      JPW1826
        STO     DIV                     JPW1827
SECD    ADD     ABCDN                   JPW1828
        STA     PUT                     JPW1829
PUT     CAL     **                      JPW1830
        LDQ     =0                      JPW1831
        LRS     6                       JPW1832
        SLW*    PUT                     JPW1833
        PXA                             JPW1834
        LRS     29                      JPW1835
        MPY     NUM,2                   JPW1836
        XCA                             JPW1837
        ADD     FXANS                   JPW1838
        STO     FXANS                   JPW1839
        TXI     TST3,2,1                JPW1840
TST3    TIX     PUT,4,1                 JPW1841
        CLA     DIV                     JPW1842
        TZE     FINISH                  JPW1843
        AXT     6,4                     JPW1844
INLOP   STZ     DIV                     JPW1845
        PXA                             JPW1846
        TRA     SECD                    JPW1847
GTFX    CLA     FXANS                   JPW1848
        ALS     18                      JPW1849
        TRA     RESULT+1                JPW1850
FINISH  CLA     FLOO                    JPW1851
        TNZ     GTFX                    JPW1852
        CLA     FXANS                   JPW1853
        ADD     FLO                     JPW1854
        STO     TEMP                    JPW1855
        CLM                             JPW1856
        FAD     TEMP                    JPW1857
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        STO     TEMP                                    JPW1858
        CLA     PTPLC                                   JPW1859
        TZE     TEND                                    JPW1860
        PAX     ,4                                      JPW1861
        CLA     TEMP                                    JPW1862
        FDP     DIV,4                                   JPW1863
RESULT  XCA                                             JPW1864
        ZET     SIGN                                    JPW1865
        SSM                                             JPW1866
 IR2    LXA     LETTER,2                                JPW1867
        LDQ     SAVE                                    JPW1868
        TIX     *+2,2,1                                 JPW1869
        TSX     NWD,4                                   JPW1870
        SXA     WORD,1                                  JPW1871
        SXA     LETTER,2                                JPW1872
        LXA     BACK,4                                  JPW1873
        STO*    2,4                                     JPW1874
        PXA                                             JPW1875
        NZT     FLOO                                    JPW1876
        CLA     ONE                                     JPW1877
        ADD     TWO                                     JPW1878
        TRA     BACK+1                                  JPW1879
 TEND   LDQ     TEMP                                    JPW1880
        TRA     RESULT                                  JPW1881
 NEND   TSX     NXTCD,4                                 JPW1882
        TRA     NUMB+1                                  JPW1883
        LXA     BACK,4                                  JPW1884
        STQ*    2,4                                     JPW1885
        TRA     BRET                                    JPW1886
 STB    SXA     STBE,4                                  JPW1887
        AXT     6,4                                     JPW1888
        PXA                                             JPW1889
        LGL     6                                       JPW1890
        LAS     COMMA                                   JPW1891
        TRA     *+2                                     JPW1892
        TRA     CMB                                     JPW1893
        LAS     BLANK                                   JPW1894
        TRA     *+2                                     JPW1895
        TRA     BLK3                                    JPW1896
        LGR     6                                       JPW1897
STBE    AXT     **,4                                    JPW1898
        TRA     1,4                                     JPW1899
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BLK3   TIX     *+6,2,1                JPW1900
       SXA     *+4,4                  JPW1901
       TSX     NXTCD,4                JPW1902
       TRA     *+2                    JPW1903
       TRA     BRET                   JPW1904
       AXT     **,4                   JPW1905
       TIX     STB+2,4,1              JPW1906
BRET   SXA     LETTER,2               JPW1907
       SXA     WORD,1                 JPW1908
       CLA     ONE                    JPW1909
       TRA     BACK                   JPW1910
CMB    AXT     7,4                    JPW1911
       TRA     BLK3                   JPW1912
READC  TSX     READ,4                 JPW1913
       TRA     NCARD+2                JPW1914
SAL    TSX     NXTCD,4                JPW1915
       TRA     *+2                    JPW1916
       TRA     NEND+2                 JPW1917
       CLA     =1                     JPW1918
       STO     DICK                   JPW1919
       TRA     CHKT                   JPW1920
NXTCD  TXL     NWD,1,11               JPW1921
       CLA     =1                     JPW1922
       STO     DICK                   JPW1923
READ   SXA     READR,4                JPW1924
       TSX     $(CSH),4               JPW1925
       P7E     FMT1                   JPW1926
       AXT     1,1                    JPW1927
       STR                            JPW1928
       STQ     BUF+1,1                JPW1929
       TXI     *+1,1,1                JPW1930
       TXL     *-3,1,12               JPW1931
       TSX     $(RTN),4               JPW1932
       TSX     $(SPH),4               JPW1933
       P7E     FMT2                   JPW1934
       AXT     1,1                    JPW1935
       LDQ     BUF+1,1                JPW1936
       STR                            JPW1937
       TXI     *+1,1,1                JPW1938
       TXL     *-3,1,12               JPW1939
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        TSX     $(FIL),4                                        JPW1940
        CAL     BUF                                             JPW1941
        LAS     =0632142256047                                  JPW1942
        TRA     *+2                                             JPW1943
        TSX     $EXIT,4                 TAKE POST MORTUM        JPW1944
RFADR   AXT     **,4                                            JPW1945
        AXT     0,1                                             JPW1946
 NWD    AXT     6,2                                             JPW1947
        LDQ     BUF,1                                           JPW1948
        TXI     *+1,1,1                                         JPW1949
        NZT     DICK                                            JPW1950
        TRA     1,4                                             JPW1951
        PXA                                                     JPW1952
        LGL     6                                               JPW1953
        LAS     =054                                            JPW1954
        TRA     *+2                                             JPW1955
        TRA     READ                                            JPW1956
        STZ     DICK                                            JPW1957
        LAS     =053                                            JPW1958
        TRA     *+2                                             JPW1959
        TRA     *+3                                             JPW1960
        LGR     6                                               JPW1961
        TRA     2,4                                             JPW1962
        TIX     *+1,2,1                                         JPW1963
        TRA     1,4                                             JPW1964
 BUFAD  CAL     *                                               JPW1965
        ANA     =0000000077777                                  JPW1966
        ADD     =21                                             JPW1967
        SSM                                                     JPW1968
        ADD     TOP                                             JPW1969
        ALS     18                                              JPW1970
        STO*    1,4                                             JPW1971
        TRA     4,4                                             JPW1972
        OCT     607777777777                                    JPW1973
 BUF    BFS     11                                              JPW1974
        PZF                                                     JPW1975
PTPLC   PZF                                                     JPW1976
BCDN    PZF                                                     JPW1977
        PZE                                                     JPW1978
SIGN    PZE                                                     JPW1979
FLOO    PZF                                                     JPW1980
ABCDN   PZF     BCDN                                            JPW1981
```

```
TEMP   PZE                                                    JPW1982
FXANS                                                         JPW1983
SAVE   PZE                                                    JPW1984
DICK   PZE                                                    JPW1985
       BCI     2,)      X,12A6                                JPW1986
FMT2   BCI     1,(1H0,5                                      JPW1987
FMT1   BCI     1,(12A6)                                      JPW1988
BLANK  OCT     60                                            JPW1989
COMMA  OCT     73                                            JPW1990
ONE    OCT     1000000                                       JPW1991
TWO    OCT     2000000                                       JPW1992
THREE  OCT     3000000                                       JPW1993
FOUR   OCT     4000000                                       JPW1994
FIVE   OCT     5000000                                       JPW1995
SIX    OCT     6000000                                       JPW1996
FLO    OCT     233000000000                                  JPW1997
       DEC     10000000.                                     JPW1998
       DEC     1000000.                                      JPW1999
       DEC     100000.                                       JPW2000
       DEC     10000.                                        JPW2001
       DEC     1000.                                         JPW2002
       DEC     100.                                          JPW2003
       DEC     10.                                           JPW2004
DIV    PZE                                                   JPW2005
       DEC     10000000                                      JPW2006
       DEC     1000000                                       JPW2007
       DEC     100000                                        JPW2008
       DEC     10000                                         JPW2009
       DEC     1000                                          JPW2010
       DEC     100                                           JPW2011
       DEC     10                                            JPW2012
NUM    DEC     1                                             JPW2013
U      COMMON  119                                           JPW2014
TOP    COMMON  1                                             JPW2015
       END                                                   JPW2016
```

```
*     LABEL
CTWO                                                                    JPW2426
      SUBROUTINE MATMPL (A,B,JIM1,JIM2,JIM3,II)                         JPW2427
C   SUBROUTINE MATMPL MULTIPLIES TWO MATRICES AND STORES THE RESULT IN ONE JPW2428
      DIMENSION A(10,42),B(10,5),TVECT(10)
      GO TO (96,97),II                                                  JPW2429
   96 DO 100 I=1,JIM1                                                   JPW2430
      DO 110 J=1,JIM3                                                   JPW2431
      TVECT(J)=0.0                                                      JPW2432
      DO 110 K=1,JIM2                                                   JPW2433
  110 TVECT(J)=TVECT(J)+A(I,K)*B(K,J)                                   JPW2434
      DO 100 K=1,JIM3                                                   JPW2435
   95 A(I,K)=TVECT(K)                                                   JPW2436
  100 CONTINUE                                                          JPW2437
      RETURN                                                            JPW2438
   97 DO 120 I=1,JIM3                                                   JPW2439
      DO 130 J=1,JIM1                                                   JPW2440
      TVECT(J)=0.0                                                      JPW2441
      DO 130 K=1,JIM2                                                   JPW2442
  130 TVECT(J)=TVECT(J)+A(J,K)*B(K,I)                                   JPW2443
      DO 120 K=1,JIM1                                                   JPW2444
  120 B(K,I)=TVECT(K)                                                   JPW2445
      RETURN                                                            JPW2446
      END                                                               JPW2447
                                                                        JPW2448
```

```
*     LABEL                                                             JPW2988
CTHR                                                                    JPW2989
      SUBROUTINE MATMPL (A,B,JIM1,JIM2,JIM3,II)                         JPW2990
C   SUBROUTINE MATMPL MULTIPLIES TWO MATRICES AND STORES THE RESULT IN ONE
      DIMENSION A(60,60),B(60,60),TVECT(60)                             JPW2991
      GO TO (96,97),II                                                  JPW2992
   96 DO 100 I=1,JIM1                                                   JPW2993
      DO 110 J=1,JIM3                                                   JPW2994
      TVECT(J)=0.0                                                      JPW2995
      DO 110 K=1,JIM2                                                   JPW2996
  110 TVECT(J)=TVECT(J)+A(I,K)*B(K,J)                                   JPW2997
      DO 100 K=1,JIM3                                                   JPW2998
   95 A(I,K)=TVECT(K)                                                   JPW2999
  100 CONTINUE                                                          JPW3000
      RETURN                                                            JPW3001
   97 DO 120 I=1,JIM3                                                   JPW3002
      DO 130 J=1,JIM1                                                   JPW3003
      TVECT(J)=0.0                                                      JPW3004
      DO 130 K=1,JIM2                                                   JPW3005
  130 TVECT(J)=TVECT(J)+A(J,K)*B(K,I)                                   JPW3006
      DO 120 K=1,JIM1                                                   JPW3007
  120 B(K,I)=TVECT(K)                                                   JPW3008
      RETURN                                                            JPW3009
      END                                                               JPW3010
```

```
*     LABEL                                                             JPW2564
CTWO                                                                    JPW2565
      SUBROUTINE RELABS (NOREL,NOCP)                                    JPW2566
C   SUBROUTINE RELABS RETURNS AN ABSOLUTE NUMBER GIVEN THE ABSOLUTE NUMBER OF
C   THE CENTRAL POINT NOCP AND RELATIVE NUMBER NOREL
      GO TO (2201,2202,2203,2204,2205,2206,2207,2208,2209,2210,2211,2212 JPW2567
     1,2213,2214,2215,2216,2217,2218,2219,2220,2221,2222,2223,2224,2225, JPW2568
     22226,2227,2228,2229,2230,2231,2232,2233,2234,2235,2236,2237,2238,2 JPW2569
     3239,2240,2241,2242,2243,2244,2245,2246,2247,2248,2249),NOREL      JPW2570
 2201 NOCP=NOCP                                                         JPW2571
      RETURN                                                            JPW2572
 2202 NOCP=NOCP+1                                                       JPW2573
      RETURN                                                            JPW2574
 2203 NOCP=NOCP-1                                                       JPW2575
      RETURN                                                            JPW2576
 2204 NOCP=NOCP+100                                                     JPW2577
      RETURN                                                            JPW2578
 2205 NOCP=NOCP-100                                                     JPW2579
      RETURN                                                            JPW2580
 2206 NOCP=NOCP+101                                                     JPW2581
      RETURN                                                            JPW2582
 2207 NOCP=NOCP-101                                                     JPW2583
      RETURN                                                            JPW2584
 2208 NOCP=NOCP+99                                                      JPW2585
      RETURN                                                            JPW2586
 2209 NOCP=NOCP-99                                                      JPW2587
      RETURN                                                            JPW2588
 2210 NOCP=NOCP+2                                                       JPW2589
      RETURN                                                            JPW2590
 2211 NOCP=NOCP-2                                                       JPW2591
      RETURN                                                            JPW2592
 2212 NOCP=NOCP+200                                                     JPW2593
      RETURN                                                            JPW2594
 2213 NOCP=NOCP-200                                                     JPW2595
      RETURN                                                            JPW2596
 2214 NOCP=NOCP+102                                                     JPW2597
      RETURN                                                            JPW2598
 2215 NOCP=NOCP-102                                                     JPW2599
      RETURN                                                            JPW2600
 2216 NOCP=NOCP+199                                                     JPW2601
      RETURN                                                            JPW2602
 2217 NOCP=NOCP-199                                                     JPW2603
```

```
      RETURN                                                            JPW2604
2218  NOCP=NOCP+201                                                     JPW2605
      RETURN                                                            JPW2606
2219  NOCP=NOCP-201                                                     JPW2607
      RETURN                                                            JPW2608
2220  NOCP=NOCP-98                                                      JPW2609
      RETURN                                                            JPW2610
2221  NOCP=NOCP+98                                                      JPW2611
      RETURN                                                            JPW2612
2222  NOCP=NOCP+202                                                     JPW2613
      RETURN                                                            JPW2614
2223  NOCP=NOCP-202                                                     JPW2615
      RETURN                                                            JPW2616
2224  NOCP=NOCP+198                                                     JPW2617
      RETURN                                                            JPW2618
2225  NOCP=NOCP-198                                                     JPW2619
      RETURN                                                            JPW2620
2226  NOCP=NOCP+3                                                       JPW2621
      RETURN                                                            JPW2622
2227  NOCP=NOCP-3                                                       JPW2623
      RETURN                                                            JPW2624
2228  NOCP=NOCP+300                                                     JPW2625
      RETURN                                                            JPW2626
2229  NOCP=NOCP-300                                                     JPW2627
      RETURN                                                            JPW2628
2230  NOCP=NOCP+103                                                     JPW2629
      RETURN                                                            JPW2630
2231  NOCP=NOCP-103                                                     JPW2631
      RETURN                                                            JPW2632
2232  NOCP=NOCP+299                                                     JPW2633
      RETURN                                                            JPW2634
2233  NOCP=NOCP-299                                                     JPW2635
      RETURN                                                            JPW2636
2234  NOCP=NOCP+301                                                     JPW2637
      RETURN                                                            JPW2638
2235  NOCP=NOCP-301                                                     JPW2639
      RETURN                                                            JPW2640
2236  NOCP=NOCP- 97                                                     JPW2641
      RETURN                                                            JPW2642
2237  NOCP=NOCP+ 97                                                     JPW2643
      RETURN                                                            JPW2644
2238  NOCP=NOCP+203                                                     JPW2645
```

```
      RETURN                                                            JPW2646
2239  NOCP=NOCP-203                                                     JPW2647
      RETURN                                                            JPW2648
2240  NOCP=NOCP+298                                                     JPW2649
      RETURN                                                            JPW2650
2241  NOCP=NOCP-298                                                     JPW2651
      RETURN                                                            JPW2652
2242  NOCP=NOCP+302                                                     JPW2653
      RETURN                                                            JPW2654
2243  NOCP=NOCP-302                                                     JPW2655
      RETURN                                                            JPW2656
2244  NOCP=NOCP+197                                                     JPW2657
      RETURN                                                            JPW2658
2245  NOCP=NOCP-197                                                     JPW2659
      RETURN                                                            JPW2660
2246  NOCP=NOCP+4                                                       JPW2661
      RETURN                                                            JPW2662
2247  NOCP=NOCP-4                                                       JPW2663
      RETURN                                                            JPW2664
2248  NOCP=NOCP+400                                                     JPW2665
      RETURN                                                            JPW2666
2249  NOCP=NOCP-400                                                     JPW2667
      RETURN                                                            JPW2668
      END                                                               JPW2669
```

```
*     LABEL                                                             JPW2449
CTWO                                                                    JPW2450
      SUBROUTINE TSF(ALFA,BETA,T)                                       JPW2451
C   SUBROUTINE TSF RETURNS THE FIRST TEN TERMS OF THE TAYLOR SERIES
C   ALFA=THE TAYLOR SERIES PARAMETER IN THE X DIRECTION
C   BETA=THE TAYLOR SERIES PARAMETER IN THE Y DIRECTION
C   T IS A VECTOR  CONTAINING THE RETURNED TAYLOR SERIES
      DIMENSION T(10)                                                   JPW2452
      T(1)=1.0                                                          JPW2453
      T(2)=ALFA                                                         JPW2454
      T(3)=BETA                                                         JPW2455
      T(4)=ALFA*ALFA/2.                                                 JPW2456
      T(5)=ALFA*BETA                                                    JPW2457
      T(6)=BETA*BETA/2.                                                 JPW2458
      T(7)=(ALFA**3)/6.                                                 JPW2459
      T(8)=ALFA*ALFA*BETA/2.                                            JPW2460
      T(9)=ALFA*BETA*BETA/2.                                            JPW2461
      T(10)=(BETA**3)/6.                                                JPW2462
      RETURN                                                            JPW2463
      END                                                               JPW2464
```